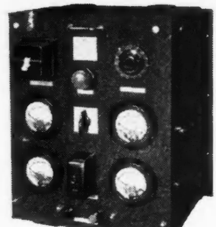
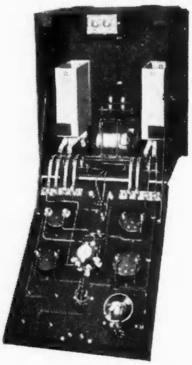
DISCOVERY

OCTOBER 1955 2/-





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DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

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THE PROGRESS OF SCIENCE

WATER POLLUTION RESEARCH

What has happened to Britain's rivers during this century has been something of a scandal, and the general public opinion is strongly in favour of a policy which will stop their contamination with noisome effluents. A particularly bad example of what should not be allowed to occur is the case of the Thames Estuary, a long stretch of which is fouled to such an extent that the black and evil-smelling water is capable of causing significant corrosion of ships and fixed metal structures.

In matters of water pollution, it is best to work on a policy derived to prevent contamination. If a new industrial process comes along, methods of rendering any waste liquors harmless should be worked out before the process is put into operation, instead of trying to correct things after a good deal of damage has been done. The problems of preventing pollution of our rivers are quite considerable ones. In Britain, for instance, treated water-borne sewage amounting to some 1500 million gallons a day has to be discharged into the rivers or into the sea. It is technically feasible for this to be done without serious pollution of the river water or harm to fish, but in fact not all sewage treatment is efficient—the sad state of the Thames Estuary is largely a measure of inefficiency in this connexion—and new plant costing £10–12 million will have to be built by the London County Council before there can be any real improvement in the condition of the River Thames. Quite tricky technical problems arise with some industrial effluents which can do great harm if discharged direct into the rivers; they can prove just as obnoxious if they are discharged into the sewers because then they may be capable of upsetting the proper operation of filter beds in sewage works.

The protection of our rivers rests primarily upon the River Boards, who employ chemists and sometimes biologists to assist them in the work of preventing pollution. Then there are the Alkali Inspectors to ensure that chemical factories do not unload obnoxious effluents to the detriment of the community at large; most of the time they can persuade manufacturers to take the steps necessary to render waste liquors inoffensive, but if persuasion fails they can start legal proceedings.

Many scientific problems arise in connexion with the disposal of waste liquors from manufacturing processes, and to assist industry with such problems the DSIR established a Water Pollution Research Laboratory in 1927. This has had a number of makeshift homes scarcely in keeping with the importance of its work, but now it is housed in adequate premises in Elden Way, Stevenage. The new laboratory, costing nearly £300,000, was officially opened on June 20 by the Lord President of the Council, Lord Salisbury. Many who attended the ceremony took the opportunity of touring the buildings and seeing something of the investigations which are being carried out there.

Inevitably, the majority of visitors were attracted by the tanks of rainbow trout on which the toxicity of synthetic detergents is being tested. It became obvious soon after housewives started using these chemical mixtures in large quantities that the surface-active agents were passing through the sewage works and reaching the rivers: this was visibly obvious in some instances, when the river water started to foam. The question was immediately asked: What effect do the amounts of detergents reaching the rivers have on fish and other organisms? Systematic tests carried out by the Water Pollution Research Laboratory show that trout can be killed by exposure to a concentration of a surface-active agent (sodium tetrapropylene benzene sulphonate, one of the basic ingredients present in proprietary detergents, has been used in the WPRL experiments) exceeding 6 parts per million. The toxicity of an average commercial detergent is rather higher than that figure. There is nothing academic about this concern with fish; they are very good indicators of the presence of poisonous substances that should be excluded from our rivers. Under the Rivers (Prevention

of Pollution) Act, 1951, River Boards were given powers to fix standards for effluents discharged to streams in their areas. That necessitates some standard test for toxicity. At present there exists no recognised standard method for making a toxicity test, but the Ministry of Agriculture is working at the WPRL on the development of a standard technique. The requirements for such a test are that all conditions shall be closely controlled and that the volume of liquid needed shall not be greater than can conveniently be carried from the factory to the laboratory. It is expected that fish of a specified kind and size will be tested in a series of dilutions of the effluent in aquaria of a standard size. Other factors which must be kept constant are content of dissolved oxygen and temperature.

This laboratory was asked to collect technical information about the pollution of the Thames Estuary. This step occurred in 1951, and was a direct consequence of the setting up by the Minister of Town and Country Planning of a special department committee to consider the effects of the discharge of effluents on the state of the Estuary. It was soon established that the foul conditions referred to earlier in this note develop when the river water is lacking in oxygen. The lowest level of dissolved oxygen is to be found in the vicinity of Woolwich when the fresh-water flow is low, and of Greenhithe under flood conditions. Fifty years ago the level of the minimum oxygen content during average summer conditions was about 25% of the saturation value; during the 1920's the figure was round 5%; while during 1947 and since 1949 part of the Estuary has been entirely devoid of oxygen throughout the July–September quarter—under these conditions hydrogen sulphide is liberated and causes public nuisance. The Laboratory's field work is finished, and extensive calculations are now in process of being made from those measurements. The conclusion has already been reached that the worst conditions in the Estuary occur near the outfalls through which the partially treated sewage of London is discharged, and it is clear that the oxygen depletion in these reaches is largely due to the presence of organic matter introduced in this effluent. Although the Departmental Committee has not yet reported, the London County Council has begun the construction of extensive plant for improving the treatment of the sewage before discharge.

The Water Pollution Research Laboratory has made important contributions to the solution of problems connected with the handling of industrial waste liquors. Some waste liquors (such as those from the food industries) can best be treated by biological processes similar to those used for the treatment of sewage. Generally, where chemical factories are involved, purely chemical methods have to be used. An interesting and exceptional case is that of the waste containing cyanide from metal-finishing plants. The cyanide has to be taken out before this can be put into sewers or rivers, and in the past this has been done by adding ferrous sulphate and some alkali (e.g. lime) to precipitate most of the cyanide as insoluble cyanides of iron. Recently the laboratory has been developing a new process which is a biological one and promises to be quite effective on the industrial scale. The basic discovery emerged from the scientists' curiosity as to what effect the waste cyanide liquor would have on a percolating sewage filter. Instead of the cyanide killing off all the micro-organisms on which sewage purification depends, it was discovered that up to a concentration of 150 parts per million the cyanide was destroyed biologically—by a member of the Actinomyces group (which have some features in common with bacteria, and in other respects resemble micro-fungi). This organism was isolated and was found to flourish and increase in size when the only "foodstuff" made available to it was a cyanide solution. The laboratory is operating one very satisfactory pilot-plant filter which handles cyanide by this biological process, and two industrial firms have erected similar pilot plants. The discovery of the unexpected capacity of a micro-organism to thrive on a diet of cyanides seems likely to find general application fairly soon.

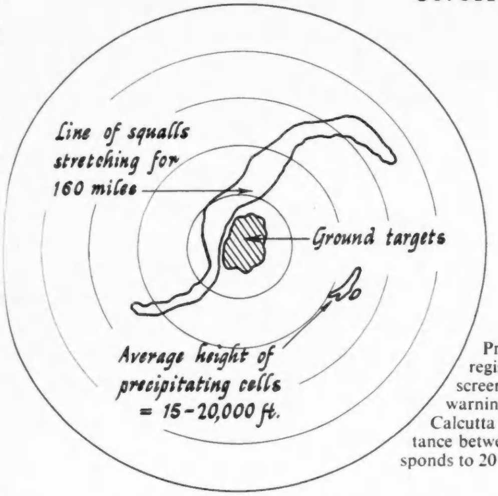
A new set of problems are being thrown up as atomic plants of industrial size increase in number; and the recently formed Radiochemical Unit of this laboratory is bound to find more and more calls being made upon its services.

RADAR AND WEATHER FORECASTING

Radar is now being used experimentally by the Meteorological Office to find out to what extent it can serve as an aid to forecasting in some detail the approach of rain and thunderstorms in the Greater London area. One aim behind the installation of the apparatus, a Decca Type 41 set, on the roof of the London headquarters of the Meteorological Office in Kingsway is to obtain information for inclusion in short-term forecasts which will be made available to inquirers. The project is regarded by the forecasting experts as experimental so far as this type of radar is concerned, although similar sets have been in use for some years in tropical countries for the detection of sudden thunderstorms.

Let us take the following example, which indicates the possible value of the apparatus in this country. The forecast for a September day in the London area might be: "Fine and sunny, but local thunderstorms probably developing during afternoon or evening." The actual sequence of weather in the area could well conform to that forecast with thunderstorms at (say) London Airport and Wembley, but the afternoon at Lord's and the Oval could remain sunny. By bringing the radar set into use it should be possible to pick up thunderstorms when and where they first begin to form. The forecaster, by following their paths on the radar screen, would be in a position to state in greater detail and perhaps some hours ahead the London areas likely to be affected.

The period of a forecast made with radar assistance varies with the weather situation. Clearly, if the set picks up moderately intense weather "echoes" at a distance of 100 miles upwind and the rain belt is moving at 25 m.p.h., a forecast could be given with accuracy, providing the conditions were maintained, three or four



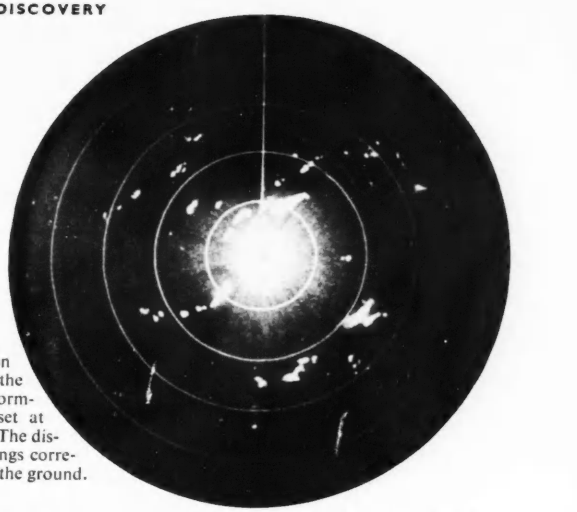


FIG. 1. Precipitation registered on the screen of the storm-warning radar set at Calcutta airport. The distance between the rings corresponds to 20 miles on the ground.

hours in advance of the weather's arrival. But as it moves there is a tendency for the weather to be modified; the radar "echoes" may die away and new ones may develop during the three- to four-hour period. This factor of change or development may not be completely covered by radar, and additional information from human observers is therefore required to complete the picture. They can, however, only cover the immediate vicinity of their stations, and the fact that a radar scanner can give a continuous report within a complete area makes it a valuable addition to the existing weather information on which forecasts are now based.

Cloud systems associated with different weather situations are characterised by varying types of radar "echo", and heavy storm-clouds, particularly cumulo-nimbus formations, can be detected at ranges in excess of 200 miles if the storm heads are sufficiently high.

Operating in the X-band within the range 9320–9500 megacycles, the Decca storm-warning radar equipment (shown in the accompanying photographs) employs a 14-foot parabolic reflector which is rotated continuously at 5–6 revolutions per minute. Bursts of energy at a peak power rating of 25–30 kilowatts are radiated about 250 times a second, each "burst" lasting only 2 microseconds or 0·2 microsecond (depending upon the range in use). During the brief intervals between each transmission the set is ready to receive an echo. The time that elapses between the transmission of the pulse of energy and the reception of its echo provides a measure of the distance covered. Bearings can be obtained with an accuracy of within one degree, the accuracy of range measurement is within 2%.

The frequencies used are capable of detecting a cloud only if it contains large particles such as raindrops, snowflakes, ice pellets or hailstones, which are known collectively as precipitation elements. Non-precipitating clouds, consisting of minute droplets of water or ice crystals, do not give sufficient response for detection by this particular set; but the recent development of millimetric radar (the X-band corresponds to centrimetric radar) promises exciting new possibilities in the detection and study of clouds.

During the past eight or nine years the Meteorological Office has operated a radar station at East Hill, near Dunstable, for basic research into cloud structure and rain, snow and hail systems, but the station by reason of its size is suitable only for research purposes and not for everyday use. Early in 1952 Decca, in conjunction with Commonwealth meteorological officers, developed a storm-warning radar to assist the operation of high-flying jet air liners in tropical regions which, though normally flying above the weather, need to be warned of sudden and severe storms before landing and take-off. This radar was specially designed to detect the presence of rainfall and show the position of heavy storm centres. By its use aircraft not only could be routed to avoid the storm, but the operator was able to plot the direction and speed of movement of the storm and so provide an accurate hour-by-hour forecast of the likelihood of rain at any nearby locality. Prototype equipment was installed at Entebbe Airport, Uganda, and

FIG. 2. A weather forecaster watches rain clouds by radar at the headquarters of the Meteorological Office.

following the success of this storm-warning radar the company developed the Type 41 set to give much greater operational range.

Readers will recall in this context the recent article on the exploration of clouds by radar which B. J. Mason of Imperial College contributed to DISCOVERY (January 1955, pp. 27–33).

THE BEE'S SENSE OF TIME

More than fifty years ago that great naturalist Auguste Forel noticed that honeybees were able to tell the time of day. In summer it was the habit of the Forel family to take all their meals on a terrace in their garden. One day a honeybee was attracted to the preserves which were put on the table at breakfast, and she signalled to her companions, who came to share the spoils with her. For a day or two afterwards these bees came along whenever the table was laid for a meal, but soon they learned to come only at breakfast and tea times—no preserves were put out at lunch-time. Forel noticed this, and so one day he had table laid *without* preserves for *all* meals; numbers of bees still came at the breakfast and tea times, but only one of them paid a visit during lunch, and this showed that the bees had learned to come only at the times at which food was usually available for them.

A quarter of a century later Fraulein Ingeborg Beling made the first careful study of the honeybees' perception of time. Individually marked bees were allowed to feed from a saucer of sugar syrup during the same two or three hours on successive days, and then on a subsequent day, during which no food was provided, their visits to the feeding-place were recorded. The accuracy of the response was found to increase with the number of days spent in the training, but bees which had been fed for a period of three hours on one day only returned during the same period on the following day. Moreover, bees were also trained to visit the same feeding-place at two or three different times of the day.

These experiments added detail and precision to Forel's observation, but Fraulein Beling could not discover how the bees were able to respond in this way. The bees could be trained to forage at any hour even when they were kept in an experimental room where the light, temperature and air humidity were kept constant. The bees' performance was not disturbed when the air in this room was irradiated to alter the degree of ionisation and so upset the rhythmic fluctuation in the electrical conductivity of the atmosphere. She concluded that the perception of time was dependent upon some unknown factor either within the bee or in its environment.

Otto Wahl, who next tackled this problem, was able to show that time perception was inborn. He was able to time-train bees which had hatched in a dark chamber and had never been aware of the alternation of day and night. He did the same thing with bees which he kept in a salt mine, a method that eliminated all the environmental factors with any clear-cut daily periodicity about them.

These results seemed to suggest that the bee has within itself a mechanism which enables it to appreciate the passage of time, and real progress in our understanding of the mechanism was made when Grabensberger investigated the effects of certain drugs on the training process. Ants, as well as bees, can be trained to visit dishes which are only made available at certain times. Grabensberger worked with both insects, and in his experiments he used quinine, which slows down many vital cell processes, in insects as in humans. He discovered that the addition to the food of the trained ants or bees of small amounts of a tasteless variety of quinine caused them to return to the feeding dishes on the following day several hours later than they otherwise would have done. On the other hand, ants fed with salicylic acid, which accelerates metabolic processes, returned earlier than they otherwise would have done.

Grabensberger was even able to train his ants to respond to 4-, 21-, 22- or 27-hour feeding rhythms, as well as to 24-hour ones. From these results he concluded that the key to the problem was to be found in the metabolism of the insects which went on steadily, not in any 24-hour rhythm. Somehow the insects use the steady rate of progress of the metabolic process to provide themselves with a measure of time.

Grabensberger's results were published in 1933. This year a more spectacular experiment has been carried out and widely reported in the daily press. In a sunless Paris room a colony of bees was trained to feed from 8.15 to 10.15 p.m. Paris time. Then the bees were loaded on to an air liner, flown to New York, and let out in a similar room in that city. The time sense of the bees was totally unaffected by their journey, and they went out to feed at 3.15 p.m. New York time, which is 8.15 p.m. Paris time. This result is in accordance with the earlier conclusions, which are summarised above.

Readers will find a good account of the work that has been done in this field in C. R. Ribbands's recent book, *The Behaviour and Social Life of Honeybees* (1953), which gives a useful set of references.

A NEW WAY OF CLASSIFYING ODOURS

The sense of smell is the least understood of all the special senses. Many more or less complicated theories have been put forward to explain its mechanism, but so far none have survived the experiments carried out to test them. Experimental work on the sense of smell has been greatly hampered by lack of an objective method of describing the characteristics of odours. All we can do to describe a smell that is new to us, is to liken it to one that is familiar, or to use more or less vague adjectives like "musty", "fragrant" and "foul". Odours have been classified on such a basis, but this kind of approach has two great disadvantages. First of all it is entirely subjective, and different noses are liable to classify odours differently. Secondly, it cannot be made quantitative.

Recently R. W. Moncrieff, a chemist who has long been interested in the subject, has devised an ingenious method by which different odours can be compared much more precisely. This resulted from his efforts to

find an objective method that would follow as closely as possible the events that occur at the sensitive nerve endings in the nose when they pick up a smell. The speed with which all smells are perceived makes a chemical mechanism unlikely. Adsorption of odorous molecules on a surface-active layer is probably the first thing that happens in the sequence of events that enables us to register smells, and this was therefore made the basis of the method. Five different adsorbent materials were chosen: activated charcoal, silica gel, activated alumina, activated fuller's earth and vegetable fat. The capacity of each of these materials to adsorb one particular odour was measured by blowing air containing the odorous substance through a glass column loosely packed with the adsorbent. The air-speed was gradually increased, until the smell could just be detected by the observer's nose at the open end of the column. The avidity of adsorption is most conveniently expressed as the "critical time of contact" of the odorised air with the adsorbent. This time is simply derived from the air-speed and the volume of the adsorbent in the column. Odours that are very rapidly adsorbed can only be blown through at high air-speeds, whereas those that are poorly adsorbed can be detected at a very low air-speed. The critical times of contact are then converted to a simple logarithmic scale, so that 0 represents very fast, and 9 very slow, adsorption. A group of five of these numbers, one for each adsorbent, thus gives a characteristic adsorption pattern for any one particular odour.

Such adsorption patterns were obtained for thirteen odorants. It was found that their number patterns were all different, just as the odours themselves were all different. Two pairs of substances which had rather similar smells also had numbers that were not very far apart. For example, two esters with a fruity smell, allyl caproate and ethyl acetate, had the numbers 2 1 5 3 7 and 2 1 4 4 9.

There was the possibility that the similarity in these number patterns might be due to the close chemical relationship between the compounds. Two further pairs of substances were therefore examined to settle this point. The first pair were natural musk whose active principle is a cyclopentodecanone, and a synthetic musk, a dinitrobenzene derivative that is commonly used in perfumes. It was found that the critical time of contact was always longer than one second, which means that none of the five adsorbents was effective in either case. The author points out that this is likely to be an important factor in nature. If musk were efficiently adsorbed by any naturally occurring material, it would not be the powerful long-range transmitter substance that it is. The other two compounds were α-ionone, which is a ketone with a ring structure, and methyl octine carboxylate—a straight chain ester. Both have strong violet odours, which resemble one another but can be easily distinguished. Their adsorption numbers turned out to be 1 1 2 2 7 and 2 1 3 2 6, which are not very different, just as the smells are. The numbers also show that both odours are very rapidly taken up by four out of five of the adsorbents, and this suggests an explanation for the fleeting nature of the violet perfume.

One other striking feature of the adsorption patterns was a general difference between the most pleasant and the most unpleasant smells. The most pleasant odours among those used were the two esters already mentioned, and oil of lemongrass, whose adsorption number was 4 2 4 4 6. The most unpleasant ones were faeces and carbon disulphide, which are characterised respectively by the numbers 0 0 9 9 9 and 4 6 9 9 9. This suggests that pleasantness of smell may go together with fairly uniform adsorption on different adsorbents, whilst extremes of difference tend to unpleasantness. If this is true, it follows that more or less uniform activation of the receptors in the nose is perceived as a pleasant smell, whilst intense activation of only a proportion of receptors produces the sensation of an unpleasant smell.

This method of characterising and classifying odours may well have important implications for the perfume industry, where in the past intuition has prevailed.

The method should also prove useful in the investigation of variations in olfactory ability. It has long been known that among individuals with an otherwise normal sense of smell some may be quite unable to detect certain odours, such as that of hydrocyanic acid, or of verbena. These different types of "smell blindness" are perhaps analogous to the different types of colour blindness. Their investigation might well clarify the genetics of olfaction in man.

It is tempting to accept Mr. Moncrieff's model of the nose as a differential adsorption chamber, and his work seems to supplement Lord Adrian's researches in a very satisfying manner. The latter has shown in many striking experiments that there are probably three major factors which enable the rabbit's nose to distinguish between different smells. Firstly, there is more than one type of olfactory nerve ending in the nose. Some endings are very much more sensitive to a particular smell than other endings. Whether there are more than two kinds of receptor is at present uncertain. The second factor in the differentiation of smells is the spatial arrangement of the receptors on the olfactory surface. Some of them lie in recesses of the mucous membrane, where the inspired air penetrates less rapidly, others are exposed to the fast current in the main channel. Such an arrangement is capable of transmitting a spatial pattern of nerve impulses to the brain, which may be fairly specific for a particular odour. The third important factor is the temporal sequence in which the receptors are activated. Some odours give rise to impulses in the olfactory bulb after a very short latent period, while others, such as the heavier oils, only act after a longer period. This may well be due to differences in the speed with which adsorption on the receptors is taking place.

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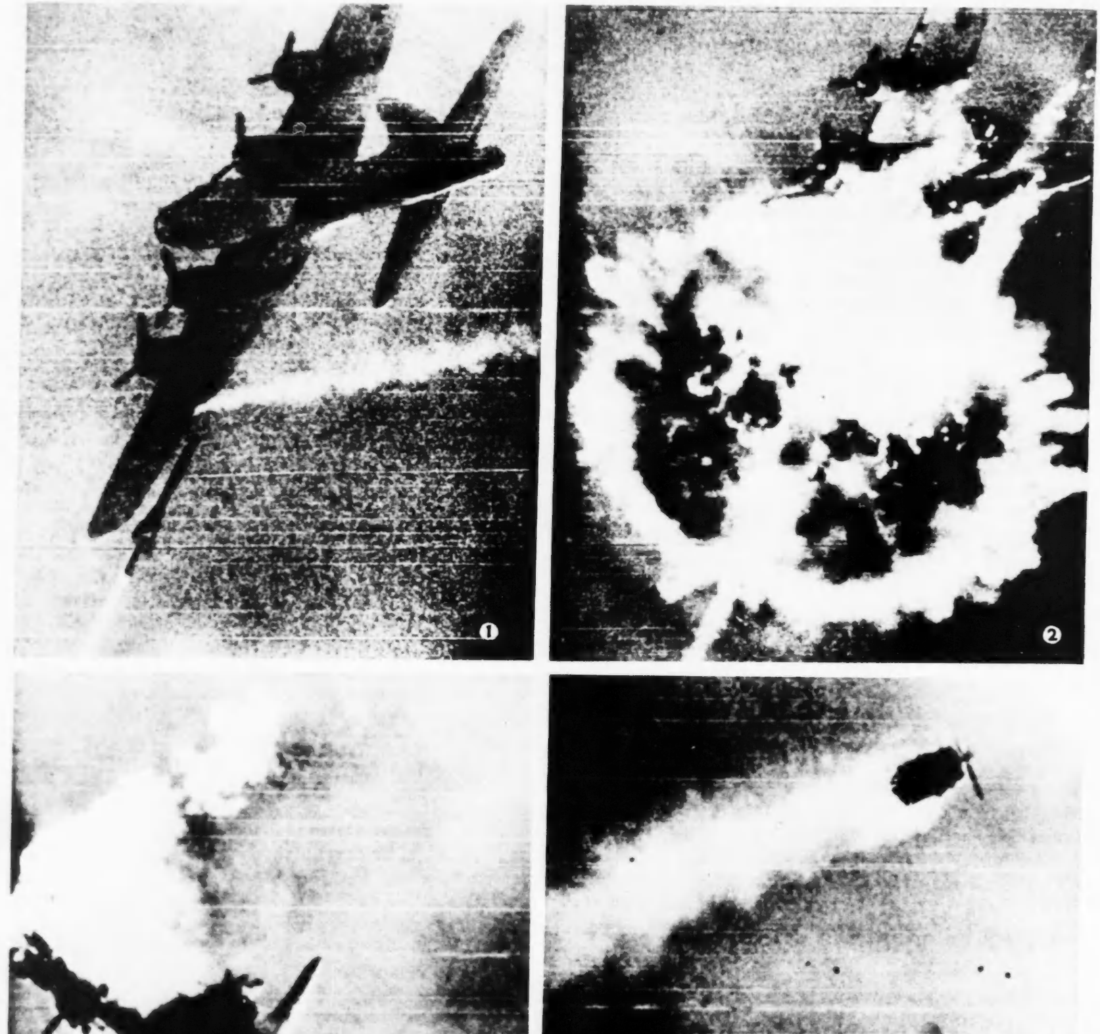


Four pictures from a cine-camera record showing a "hit" registered by NIKE, one of the U.S. Army's guided missiles, on a four-engined bomber flying over the White Sands proving grounds.

1. NIKE engages the target plane. 2. The missile explodes. 3. Target plane with one wing shattered and on fire. 4. High above the wrecked plane flies one of its engines, torn from the wing by the force of the explosion.

THE PROBLEMS OF GUIDED MISSILE DEVELOPMENT

CHAPMAN PINCHER

It is now eight years since the Government began earnest work on the development of guided missiles, taking up the many lines of research developed by the Germans. Many millions of pounds have been spent. A high proportion of the aircraft and electronics industries—more than 1500 firms in all—is engaged on guided missile research and development work. Yet not one guided weapon has yet been delivered to the Services. The Government has had to borrow guided missiles from the Americans so that Army troops can be trained in handling them.

What is the reason for the long delay? Economic difficulties, political indecision and ineptitude by the Civil Service have been frequently cited, but the chief cause of the delay has undoubtedly been the immensity of the technical problems involved.

Consider the performance requirements of a ground-launched anti-aircraft missile, for example. It must be able to carry as much as 200 lb. of high explosive to a height of 60,000 feet at speeds which enable it to intercept a bomber flying at perhaps 1000 miles per hour. To be effective it must explode within 100 yards of its target which is probably pursuing an erratic course. This means it must be able to manœuvre at accelerations of between 10 and 20 G which put a terrific strain on its structure. To move its controlling surfaces under such conditions it must be able to supply considerable power to its servo-motors.

It must be so simple and reliable to operate that troops can launch it within the 10-minute warning time which is all they can expect. (To allow for the speed of the bomber, the firing of the missile and its flight to the target, the launching crew must be alerted when the bomber is no nearer than 200 miles.) Finally it must be highly resistant to the "jamming" of its radio control system by the enemy.

These formidable requirements inevitably mean that any effective missile system—the weapon and the ground-control equipment—is fantastically complex. In the U.S. NIKE rocket and its control system there are more than 1,500,000 separate parts and this weapon has only a limited performance.

Little work of importance on guided weapons could be begun in Britain until special facilities were created. The aerodynamic problems, for instance, could be solved only by experiments in supersonic wind tunnels which did not exist. These problems embrace not only those of the "sound barrier" but those of the "heat barrier" too.

The Government's initial plan was to set up a central guided missile station at Westcott, Bucks, but this was changed and research was centred instead on the Royal Aircraft Establishment at Farnborough, the role of the Westcott station being restricted to the development of propulsion units. The original decision that the Government establishments would be responsible for development as well as research on guided weapons was also changed and the bulk of the development work was handed over to industry.

Shortage of scientists and technicians in this novel field was naturally a limiting factor in the early work, but in the last few years the Government and industrial concerns have built up departments in which many hundreds of guided weapons specialists are now employed.

A comprehensive series of wind tunnels has been built at the Guided Weapons Department of the Royal Aircraft Establishment, and at the National Aeronautical Establishment, Bedford, and Britain is now particularly well placed for this facility.

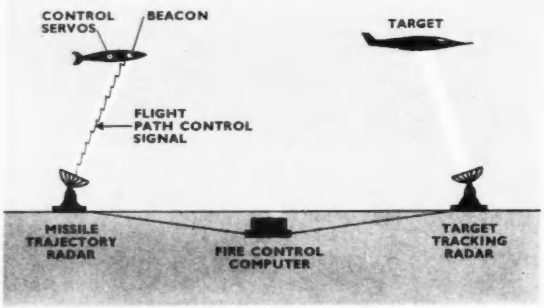
Because of the expense and difficulties of testing guided weapons in flight, it was soon realised that effective methods of simulating the flight of missiles in the laboratory would have to be devised. This itself was a formidable problem but some remarkable devices have been built, perhaps the most effective being TRIDAC. This giant computing machine, which is now in full operation at Farnborough, not only handles numerical ballistic data with great speed, but also provides a visual three-dimensional picture showing exactly what happens when missiles of different performances are fired against their targets.

A further facility which will help to speed guided-missile work is the large centrifuge recently opened at the Institute of Aviation Medicine. Though primarily intended for the investigation of the effects of gravity on aircrew it may also be used for the testing of missile parts for which purpose it can simulate the effects of 30 G's.

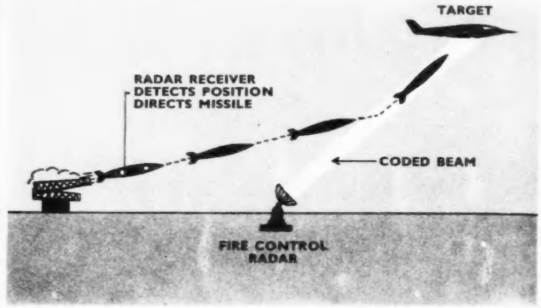
The peculiar fuels required for rocket flight such as liquid oxygen, nitric acid and hydrogen peroxide have posed their own problems but it is in the development of guidance systems that the toughest difficulties have been encountered. Not until the form of the control system of each missile has been decided can the design of the fuselage, wings and propulsion unit be finally settled.

"BEAM RIDING" AND "COMMAND SYSTEM"

A missile may require different kinds of guidance at three stages of its flight—guidance in the launching phase, mid-course guidance and terminal guidance. Guidance in the launching phase is fairly simple, the missile usually being "gathered" into a cone of radio waves which puts it in the right direction. Mid-course guidance can be achieved by several methods the simplest of which is "beam-riding". In this system a



COMMAND SYSTEM



BEAM RIDING

The COMMAND SYSTEM consists of two separate fire-control radar sets linked with a computer. When the general warning system signals the approach of an enemy aircraft, one set begins to track the plane as soon as it comes within range. The missile is launched at a suitable moment and its flight-path is tracked by the second radar set. Signals from both sets are fed into the computer which continuously plots the path the missile must take to intercept its target. The computations are then automatically signalled as instructions to the missile. Ground controllers can watch both missile and target on the radar screens. BEAM RIDING. A radar set based on the ground or in an aircraft forms a narrow beam which locks on to the target plane. The missile is fired up the beam. A device fitted within the missile automatically corrects any tendency to stray out of the beam.

radar device operating from the ground or from another aircraft locks on to the target and the missile rides the beam. In practice this is not so simple as it sounds because the beam tends to be reflected from different points of the aircraft at different times, and with a large bomber this can cause inaccuracy. In the "command system" which enables missiles of simpler construction to be used, information about the target's future position is transmitted to the missile as instructions which operate its control surfaces and steer it.

In some of the more sophisticated systems now under development both methods are used at once to provide greater accuracy. The missile beam-rides while ground-based transmitters locate the target and keep it informed of its flight path.

For very long ranges automatic navigation with reference to certain stars may be necessary and it is significant that at least one British firm working on guided missiles has recently advertised for scientists with knowledge of celestial mechanics.

"HOMING"

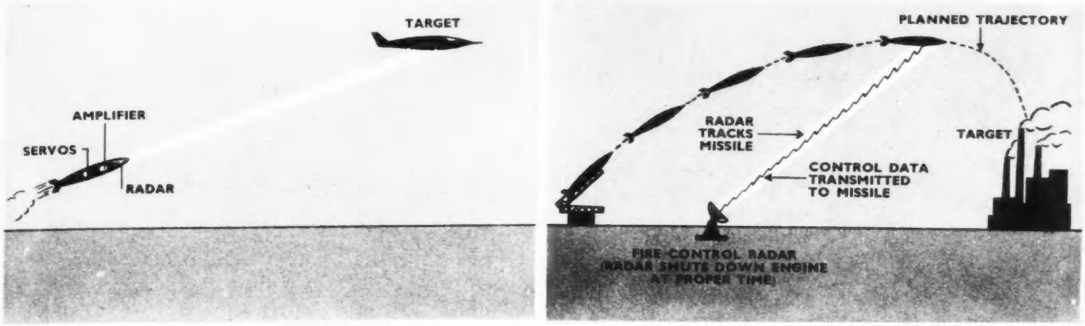
Terminal guidance may be achieved either by *passive homing*, when the missile is attracted by a source of energy such as heat or noise given off by the target, or by *active homing*, where it gives off radio signals which are reflected back to it from the target. For active homing the missile must carry a transmitting set as well as a receiver. There is therefore a difficult weight problem to be overcome if the missile is to have long range. This can be reduced if the transmitter can be located in a "mother aircraft" or on land—a system which has proved accurate at ranges of less than 20 miles.

The whole guidance problem is further complicated by the fact that with very fast aircraft it will be impossible for the missile to pursue the target directly, as such a course would demand impossible accelerations within the range limit set by fuel capacity. It may therefore be necessary for the missile to be fired considerably above the target into the thin upper air where it will have greater range, but this means that the missile must somehow connect with the target on its downward path back to earth again.

It will be realised that extremely complex radar devices are involved in most guided missile systems and the immediate demands on radar performance have occasionally been greater than the radar technicians could fulfil. In the main, however, radar research has been sufficiently advanced so that it has not constituted a bottleneck.

The testing of a guided missile during the development phase is necessarily a lengthy business. Not until most of the components have reached a satisfactory state in static tests on the ground can the propulsion unit be tried in flight. After its range and altitude performance is satisfactory the propulsion unit must be tested again in conjunction with the electronic and servo-mechanisms which make up the guidance system. It may then happen that in real flight the guidance system which has worked perfectly in simulated flight conditions on the ground fails for some unexpected reason. Vibration or extraneous noise from the propulsion unit may affect the guidance mechanism so much that the designers may have to go back to the drawing-board and modify their ideas

It is of course essential that a missile should be resistant to "jamming" by the enemy. For this reason many guidance systems which would get the missile to its target in the absence of any enemy counter-measures are ruled out or have to be very greatly modified. The "jamming" danger means that the designers must continuously anticipate what an enemy might do if faced with the missile and must make use of what information they can get from the Scientific Intelligence men



ACTIVE HOMING — PLOTTED TRAJECTORY

ACTIVE HOMING. The missile which actively homes to its target carries a transmitting set as well as a receiver. It sends out radar signals which are reflected back to it from the aircraft it is intended to intercept. These echoes are picked up by the missile's receiver and control its course to keep it on target. PLOTTED TRAJECTORY. The truly ballistic missile is fired on a preset course calculated according to the principles of ballistics. Radar interference is used solely to cut off the missile's fuel supply at the right moment so that it does not overshoot the target. Because of the inevitable inaccuracy, this system is intended for use only with ground-to-ground or ship-to-ground missiles.

about foreign developments in the guided weapons field.

This problem is being tackled by a team of scientists whose main function is to outwit the designers so that their missiles fail to reach their targets. Most tests of these "enemy" devices can be carried out in simulated flight on the ground—with TRIDAC for instance—but the missile cannot safely be considered ready for production until it has passed "jamming" tests in flight-trials against targets. Occasionally the "jamming" experts have their victories over the designers who have to think up some new method of protecting the missile from interference—which may again delay the day when the weapon goes into production.

A further time-consuming factor is the difficulty of testing the missiles against anything like the targets they are expected to encounter in action. Ideally the targets used in anti-aircraft missile research and practice should be "drone" forms of the aircraft which will be flying when the missiles reach the Services. The nearest approach to this impossible ideal is the use of four-engined bombers, jets and robot rocket-planes like the Jindivik, in ways which simulate the performance of future aircraft as closely as possible.

In trials carried out off the British coast drone aircraft of this type have been used, but usually piloted planes just out of the missiles' actual range serve as targets. In "drone" experiments the warhead of the missile can be filled with a marking powder which is scattered by a small opening charge when the proximity fuse functions. The drone is seen to be marked when it returns to base if the shot has been successful.

In at least one case a drone aircraft has been holed by a missile which went right through it. This missile was not fitted with an explosive warhead which would have destroyed the target. Being expensive, the targets are saved whenever possible.

Full details of performance are radioed back by telemetering apparatus fitted in the missile, and the ground-control crew can tell whether the missile got within lethal range of its objective, for the explosion of the proximity fuse can be detected.

Direct hits on aircraft would be rare under combat conditions because normally the warhead should operate as soon as the missile approached within about 100 yards of its target.

It is essential that anti-aircraft missiles shall finally be tested at the great heights—60,000 feet and above—at which they will have to operate. This is not possible off the British coast because of the danger to shipping, so that full-scale tests have to be carried out at the Woomera weapons testing ground in Australia. There is a good air-ferry service between Britain and Woomera but the great distance and the time involved are further delaying factors. Highly effective tracking equipment, telescopes, theodolites and ballistic cameras for following the flight of experimental missiles have been built and the evidence of these instruments coupled with the telemetered information could satisfy the scientists about a missile's effectiveness, but the Service chiefs who place orders for the weapons are usually not convinced until they have seen a weapon do the whole job for which it is intended. So after numerous tests with "cold" missiles—missiles not fitted with a warhead—the complete "hot" missile must eventually be fired in a way which shows that it can knock down an aircraft, in the case of an anti-aircraft weapon, or blow up its objective in the case of a land-burst rocket. Such trials must be carried out in the wastes of Woomera.

It will be realised that the R.A.F. which is to be responsible for ground-to-air defence with guided missiles will be faced with a serious training problem in spite of what can be accomplished with flight-simulators. Presumably any live practice under operational conditions will also have to be done at Woomera. Such

An English Electric guided missile at the moment of "boost separation". The booster rockets, which have helped to give the missile its tremendous velocity, have served their purpose and are discarded.

practice will be restricted as much as possible because of the expense, but the R.A.F. must surely insist on the routine firing of some rounds under combat conditions.

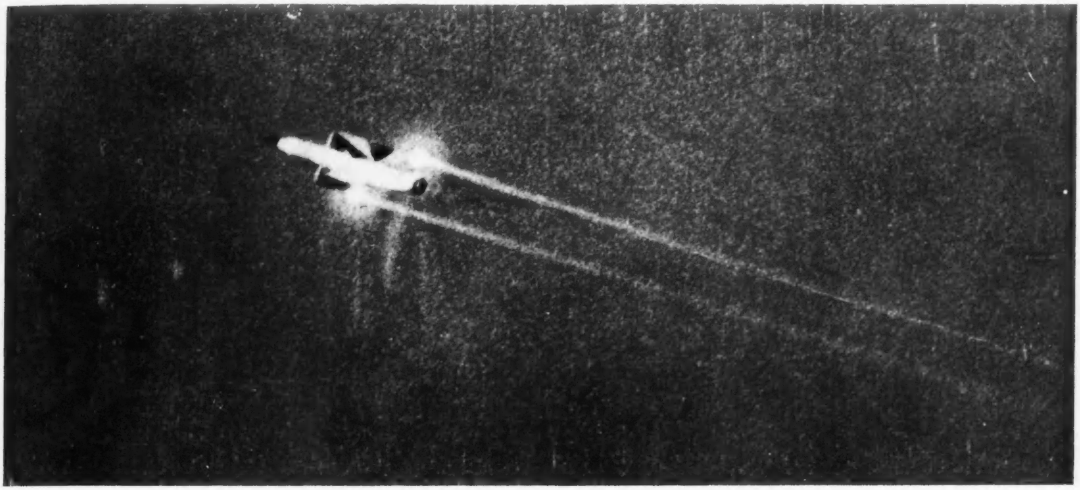
Even greater limitations are imposed on the testing of missiles with atomic warheads. It is the Army's intention to equip the Royal Artillery with such weapons and a small party of British officers and N.C.O.'s has gone to the U.S.A. for six months' instruction in the operation of the American "Corporal" Mark II ground-to-ground missile. British atomic warheads capable of fitting such a missile are already in production but something better than the "Corporal" is required by the Royal Artillery. (In this context it is worth recalling that the British Army has no intention of developing huge atomic guns like the U.S. 280-millimetre cannon, which has a small range compared with the "Corporal's", is difficult to manœuvre on soft terrain and is extremely wasteful of atomic explosive. The limited space inside the thick-walled shell greatly reduces the efficiency of the mechanism for detonating the atomic explosive—a drawback from which the guided missile does not suffer so severely.)

In spite of all these difficulties, the Ministry of Supply could undoubtedly have produced some missiles for the Services but for one over-riding requirement—every missile must be as near as possible 100% reliable. Anything but the smallest proportion of "dud" rounds is unacceptable, primarily because of the marginal time the defence will have to use the weapons and secondly because of their cost. Once they are in the hands of the Service which is to use them the missiles must remain reliable in storage for long periods so that they are fireable after only the smallest amount of adjustment by Service technicians. On top of this the missiles must be so designed that every item can be tested for efficiency immediately before firing. The provision of testing equipment for this purpose (which must be simple to use in the field and yet must indicate that every part is in working order) sets quite a problem for the designers.

In all these developments the Americans are undoubtedly well ahead of the British—probably two years ahead. They were able to start in earnest a good deal earlier, because of Britain's difficult economic position after the war and they have had a bigger programme going throughout. They have also had the continuous benefit of no less than one hundred and twenty of the best experts who belonged to the war-time German rocket research team. Each of the U.S. Services is spending about £10 million a year on rocket research. The three U.S. Services seem to have almost entirely independent guided-missile programmes in active competition. This is perhaps a luxury which America can afford but a better co-ordinated programme might result in quicker results for less money.

Apart from the advantage which the Americans have had in money, materials and man-power, Britain has suffered from the handicap that defending this country from possible air-raids by means of guided missiles is rated as substantially harder than the Americans' problem. Because of the ranges involved it is doubtful that U.S. cities could be subjected to massed bomber attacks whereas any British city is open to them.

This helps to explain why Britain has not yet developed a missile like NIKE—the U.S. weapon currently being manufactured to protect Washington, New York and other key points. The performance of NIKE is not considered good enough for British purposes though it has taken eight years of intensive work to produce it. NIKE's guidance system tends to be "saturated" by two aircraft. If it is fired into a region of the sky where there is more than one enemy plane, its "brain" becomes confused so that it cannot make up its mind which target to attack and its velocity peters out before it has attacked any. To guard against mass



This second photograph shows this English Electric missile closing on its target with a velocity far above the speed of sound.

bomber attacks Britain needs much "brainier" missiles than NIKE.

This "saturation" problem complicates the trials difficulties still further. After passing all its exhaustive tests each missile must then prove itself in trials where two targets are presented at once to see how well its built-in "brain" can concentrate on one target and ignore others.

The first British weapons to reach the user will be air-to-air rockets, i.e. missiles carried by one aircraft for use against another. These are scheduled to be in production by 1957. No details of these weapons are available, but presumably they will be powered by solid propellents such as cordite and be guided by radar with possible infra-red homing devices for the final stage of the flight. Instead of engaging at ranges measured in yards, the aircraft of the future will fight at distances up to a mile and beyond.

As the new White Paper on Defence indicated, anti-aircraft guns will eventually be replaced by guided missiles except for targets specially susceptible to low-level precision bombing. The R.A.F. have taken over responsibility for home defence with guided missiles but it is expected that anti-aircraft defence in forward battle-field areas will remain in the hands of the Royal Artillery.

Anti-aircraft guided missiles are unlikely to be available for the Services in quantity much before 1960.

There is an urgent requirement for a reliable anti-tank guided missile which could be fired by artillerymen or by tanks themselves. Equally obvious is the need for an air-to-water guided missile which could be fired at submarines located by sonobuoys. Naval requirements for guided missiles are extensive—ship-to-shore and ship-to-air missiles being urgently needed. There would not seem to be much requirement for ship-to-ship missiles to replace naval guns, however. In any fore-seeable "hot" war naval engagements between big ships are unlikely. Indeed it is doubtful whether any big ships will exist apart from aircraft carriers, and these will tend to get smaller as vertical take-off and landing methods for aircraft are perfected. Any capital ships put into action by an enemy could be attacked most effectively by guided weapons fired from aircraft.

The British and U.S. guided-missile programmes are based on the supposition that piloted aircraft with speeds below 1000 m.p.h. will constitute the main attacking force of any enemy in the foreseeable future. But the ballistic missile—the super-speed rocket which can be preset on its course with fair accuracy and needs no radio guidance must soon be taken into account. There are some experts who think that it may be a going concern by the time guided missiles become really effective against aircraft.

The U.S. Government has already revealed some details of an inter-continental rocket called Atlas which is now under development. It is designed to have a range of 5000 miles and will probably weigh 100 tons at launching. Its speed may be as high as 10,000 m.p.h. at some stage of its trajectory. Could guided missiles intercept such weapons and destroy them?

Bearing in mind that it has never proved possible to intercept a shell once it has been fired from a high-velocity gun, the odds are that no adequate defence against ballistic rockets will be possible. That prospect may alter somewhat if the programme for developing guided rockets carrying hydrogen bombs is carried through to a successful conclusion. Little has been published about the U.S. project concerned with such weapons, though the chairman of the Senate atomic energy sub-committee which deals with military applications has stated that in a relatively short time America will have missiles which would "explode high in the air, carrying hydrogen warheads capable of knocking down an entire approaching enemy air armada".

ATOMS FOR PEACE

"At hand is a rich opportunity to restore old ties of free scientific communication which have been disrupted for so many years." That was the outstanding point in President Eisenhower's message which was read at the opening of the international conference on the peaceful uses of atomic energy. The conference which met in the Palais des Nations from August 8 to August 20 made the fullest possible use of that opportunity. Not only in its seventy-odd sessions, but outside the conference rooms, when atomic scientists who had been unable to meet and discuss matters of mutual interest for so many years were able to establish those direct personal contacts which are invaluable in scientific work. There is no doubt that the conference led to the declassification of much information about the progress of nuclear research and development by the three big "atomic powers"—Britain, the U.S.A. and Russia. Indeed the leader of the American delegation stated that the preparation of papers for the conference had definitely led to declassification of facts hitherto only known to experts working for the U.S. Atomic Energy Commission.

The sheer bulk of papers presented to the conference can hardly be realised from the bare fact that their total weight amounted to two hundred tons. One single complete set of papers—numbering nearly a thousand, of which some three hundred were actually read at Geneva—made a pile about five feet high! But as was implied by the Secretary-General of the United Nations speaking at the opening session, statistics—he had just referred to the fact that seventy-two nations were represented at the conference—did not bring out the unique quality of the gathering. But its uniqueness must have been sensed by everyone who listened to Mr. Hammarskjöld pose the question: When in the history of mankind have men of knowledge (so many men, he might have said), representing so many diverse and distant nations, congregated to offer the best of their minds and goodwill in order to promote knowledge and, through knowledge, peace? A full answer to the question could include many points, one of which is that never before in history have nations shared the secrets of a new source of power to the extent that they did at this conference, as the science correspondent of the B.B.C.'s European Service pointed out in one of his broadcasts from Geneva. The atomic power aspect of the conference and the two associated exhibitions brought to Geneva many interested in the industrial and financial prospects of this new power source, and stockbrokers and business men were to be seen rubbing shoulders with the nuclear scientists and engineers. The firms connected with Britain's atomic power programme sent a strong contingent; among the firms represented by observers attached to the British delegation were English Electric, A.E.I., G.E.C., C. A. Parsons, Tube Investments, Babcock and Wilcox and Head Wrightson Processes. Also noteworthy is the fact that Bristol Aircraft, Hawker Siddeley, De Havilland and Rolls-Royce sent official observers.

In his opening address the president of the conference, Dr. Homi Bhabha, who is chairman of the Indian Atomic Energy Commission, spoke of the energy needs of the world and of the "power famine" that was in prospect before ways of tapping nuclear energy were discovered. All the fossilised fuels like coal and oil will be exhausted in less than a century, he said. "There is no longer any question that atomic energy can be used for power generation," he went on, and quoted an estimate that world reserves of uranium and thorium contain energy of the order of 1700 Q. (Q is the very large unit commonly used when considering the world's power needs: it is equal to a million million million British thermal units, corresponding to the combustion of about 33,000 million tons of coal.)

Dr. Bhabha described the basic ideas of atomic energy as simple, though its technology is sophisticated and difficult. Unlike coal furnaces, which differ in detail but are basically all of the same design, atomic furnaces can be of at least half a dozen basically different designs, differing in the physical and chemical states of the fuel, the moderator (if any) and the method used for extracting the heat. (Taking into account all the variable factors possible in atomic furnace design, one speaker at the conference suggested a figure of over nine hundred for the number of different types of atomic furnaces that are theoretically possible.)

Atomic power production involves the disposal of large amounts of fission products and the risk of radiation escaping into the air. These, he said, called for extreme care. Dr. Bhabha described the direct biological effects of radiation as fairly well known, and added that safe tolerance doses can be prescribed, though expert views on these differ. Not enough is known about the indirect effects, above all the genetic effects. "This is too important a matter for any risk to be taken. Our first duty as scientists is to establish the truth, and in this matter our responsibility to humanity transcends our allegiance to any state," he said.

The existence of atomic weapons, though these were outside the scope of the conference, was not ignored by Dr. Bhabha who pointed out that the rise of an atomic power industry would put into the hands of many nations quantities of fissile materials, from which atomic bombs could easily be made. "A widespread atomic power industry will necessitate an international society in which the major states have agreed to maintain peace."

Towards the end of his speech Dr. Bhabha ventured "to predict that a method will be found for liberating (hydrogen) fusion energy in a controlled manner within the next two decades. When that happens, the energy problems of the world will truly have been solved for ever, for the fuel will be as plentiful as the heavy hydrogen in the oceans." This prediction kept the Press correspondents busy for almost the first week of the conference, and on the guarded statements of Sir John Cockcroft and Admiral Strauss of the U.S. Atomic Energy Commission to the effect that both Britain and the U.S.A. are working on the hydrogen-fusion process were based some highly imaginative stories which appeared all over the world about the progress made towards the tapping of this possible source of power. Hydrogen fusion, however, was not discussed in any of the conference sessions; all that was said about it publicly at Geneva, apart from Dr. Bhabha's remarks, was contained in questions and answers at several Press conferences.

Out of the vast number of papers delivered to the conference it is only possible for us to mention a few. The English edition of the full proceedings of the conference should be published by the United Nations at the end of the year. They are expected to fill sixteen volumes, and presumably it will be possible to purchase them in Britain from H.M. Stationery Office, as is usual with U.N. publications. In the meantime a complete set of the Geneva papers can be consulted in the library of the U.N. London Office, the address of which is 14–15 Stratford Place, W.1. For the benefit of readers who want to trace in that library a particular paper that we refer to, we give the necessary reference number which the conference preprint carried. The full proceedings will be available in French and Russian in the spring, and the Spanish edition will appear some time later.

Power Reactors

Discussion of power reactors occupied no less than four complete sessions. As Britain is nearer to atomic power production on a large scale than any other country, the papers by A.E.A. experts such as Sir John Cockcroft, Sir Christopher Hinton and Dr. J. V. Dunworth were listened to with particular attention.

Sir John Cockcroft gave a very succinct account of the contribution nuclear power is likely to make in Britain in the next twenty years, and summarised the plans published earlier this year in the Government White Paper. As readers will recall, the

Central Electricity Authority plans to complete twelve power stations in the period 1960–65, during which time the output of the individual station is expected to rise from 100 megawatts to at least 200 megawatts. The total installed capacity should exceed 1000 megawatts by 1965, and reach 10,000–15,000 megawatts by 1975. Said Sir John: "By 1975 nuclear power should be doing the work of at least 40 million tons of coal a year—providing about 40% of the energy for electricity."

Britain's first nuclear power reactors will be graphite-moderated, and with a single fuel cycle these should give the heat equivalent of 3000 megawatts per ton of uranium, equal to that of 10,000 tons of coal. Probably the percentage of heat extracted would be determined by the deterioration of the fuel elements rather than by nuclear factors. Plutonium accumulates in the fuel elements of this type of reactor along with fission products. The latter will be extracted chemically, and the uranium and plutonium can then be recycled; alternatively the plutonium can be used as a feed to other types of thermal reactors (e.g. water-moderated reactors requiring enriched fuel or fast breeder power reactors). Sir John then mentioned the paper which Dr. Dunworth presented later to the conference, and which showed that it should be possible to recycle uranium and plutonium fuel several times until the concentration of U235 has been reduced to a low figure and an appreciable amount of U238 has been fissioned. "In this way it may be possible to increase the heat extraction per ton of uranium from 10,000 tons of coal to as much as 100,000 tons," said Sir John.

This phase, which should see a tenfold rise in the efficiency of utilising the uranium fuel, would be likely to bring reactors of higher rating and output. Sir John said that water-moderated reactors now under study in Britain showed considerable promise as possible successors to graphite-moderated reactors.

The next phase, which could bring a further tenfold improvement in uranium utilisation (1 ton of uranium would then do the work of 1 million tons of coal), may be expected when fast breeder power reactors come into industrial production. The amount of secondary plutonium fuel bred in such reactors from U238 should be greater than the plutonium fissioned in the core. In the experimental Harwell fast reactor called ZEPHYR two plutonium atoms have been created for each plutonium atom fissioned, and some such gain should prove possible with industrial plutonium fast reactors, though the gain factor would certainly be less than in ZEPHYR.

Extrapolating to the year 2000 Sir John Cockcroft saw Britain meeting its energy needs by burning 250 tons of uranium or thorium a year and getting power equivalent to that from 250 million tons of coal. "The emerging shortage in world supplies of the conventional fuels might be met by producing the greater part of world electricity supplies in nuclear-power stations consuming 2–3 thousand tons of uranium or thorium a year for the purpose."

The potential value of thorium as a fuel was considered by Dr. Dunworth of Harwell in a paper (403) on fuel cycles and types of reactor. He believed that chemical, metallurgical and nuclear consideration would favour power piles using the thorium–U233 fuel cycle rather than a cycle based on U235, Pu and U238: the fissile U233 is produced by thermal or non-thermal neutron bombardment of thorium in the reactor, which he said "will be about self-maintaining in fissile material". This was one of the two distinct types of systems Dr. Dunworth favoured when it came to deciding which lines for developing high-powered reactors offered most promise. The other system, he said, was the fast or slightly moderated fast reactor which can lead to very high gain factors using the Pu–U238 fuel cycle, and a rather lower one using the thorium–U233 cycle.

Britain's Gas-cooled Reactors

Sir Christopher Hinton (406) set out very clearly the reasons why the Atomic Energy Authority pins so much faith in the graphite-moderated, gas-cooled pile (e.g. Calder Hall) for power production in the immediate future. It is inherently stable and does not demand isolation in the interests of safety; force of geographical circumstances led Britain to concentrate on this kind of pile, instead of the graphite-moderated water-cooled reactors favoured in America where safe sites far from big centres of population are abundant. It is reasonable to think of nuclear reactors in an ascending scale of specific heat rating of their fuel elements. At the bottom of the scale is the Calder Hall type; at the other end is the fast fission reactor, very much more highly rated and using expensive and rare materials of construction. Sir Christopher described the first kind of pile as the slow-speed reciprocating engine of the nuclear reactor world; the fast fission reactor as the counterpart of the gas turbine. "It would be a great mistake to assume that these conservatively designed ["Calder Hall" type] reactors have only a limited future. With development, the reciprocating steam engine held its own over a period of over 200 years, and the simplicity and reliability of the gas-cooled reactor will entitle it to a similar plan in the history of nuclear power."

Very many different kinds of design for power reactors can be envisaged, and one author at the conference said that over nine hundred kinds were possible. Dr. Dunworth explained how the possibility of using any one of four fluids for cooling the pile (gas, heavy water, light water, sodium) and any one of four moderators (beryllium, carbon, deuterium, hydrogen) had to be considered about 1950 when Britain was making plans for future reactors. Each of the sixteen different combinations of these materials were considered before deciding on which type of reactors offered the most promising short-term possibilities. Gas-cooled graphite reactors had the advantage that they needed no initial enrichment but could run on natural uranium. Sodium cooling was regarded as worth subsequent but early attention. The second good line of development seemed to be a reactor moderated and cooled with ordinary water; the use of an organic liquid as the moderator also deserved consideration.

The experimental fast reactor project at Dounreay was described by J. W. Kendall and T. M. Fry (405). This has the most flexible design possible, enabling modifications to be made to it for the purpose of obtaining the knowledge needed for the development of a fast power reactor that is a sound economic proposition. Fast reactor cores must contain a much higher proportion of fissile material (either U235 or Pu 239) than is present in natural uranium. This means that the initial charge represents a large capital investment, and therefore the aim in developing such reactors as power generators must be to get hundreds of kilowatts of electricity from each kilogram of fissile material. The core size of the Dounreay experimental reactor is about 2 feet in diameter and 2 feet long. The core and its blanket is contained in a stainless steel pot. The cooling fluid will be sodium potassium alloy; later pure sodium, which is a better heat transfer medium but solidifies at a higher temperature, will be used. Circulation of the fluid will depend on electromagetic pumps, and no valves are included in the cooling circuit. The neutron shield around the pot consists of graphite 4 feet thick; most of this graphite contains enough boron to "soak" up the neutrons when they have slowed down. The biological shielding consists of a concrete bowl about 90 feet in diameter, and 5 feet thick; on top goes a roof slab of concrete (supported by vertical columns) and from it hang the heat exchangers. The whole reactor will be enclosed in a steel sphere 135 feet in diameter, and 1 inch thick. These arrangements are so designed that if the most serious accident possible should occur and all the sodium caught fire there should be no risk of the steel sphere rupturing.

Russia's First Power Reactor

A useful review of fast power reactor schemes was given by Dr. W. H. Zinn of the U.S. Argonne National Laboratory (814). Dr. Zinn is, of course, one of the world's greatest experts on nuclear reactors; his experience dates right back to 1942, when he worked in

THE GENEVA CONFERENCE AND EXHIBITIONS

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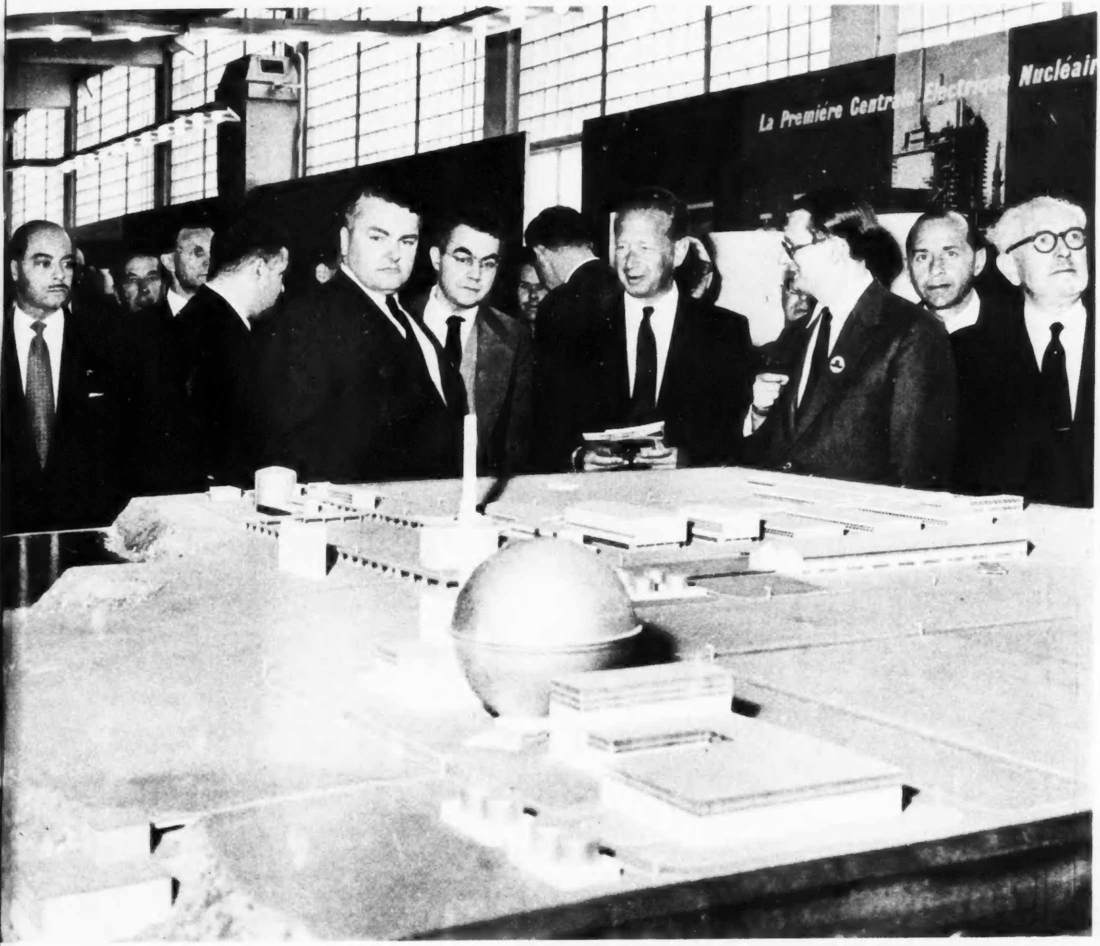
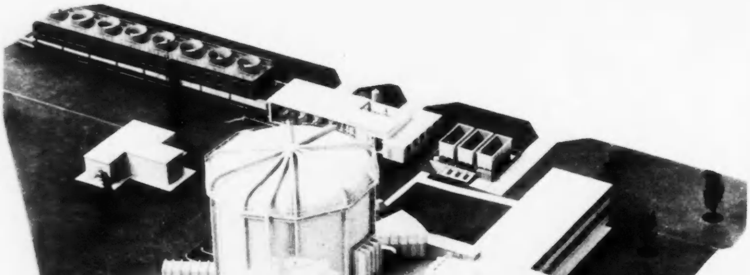
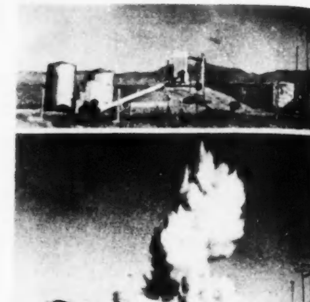


(*Top opposite*) The president of the Geneva Conference, Dr. Homi Bhabha. With him are the leader of the Russian delegation, Prof. D. V. Skolbetzin (*centre*) and Sir John Cockcroft (*right*).
(*Bottom opposite*) The opening session of the International Conference on the peaceful uses of atomic energy on August 8. Seventy-two countries were represented.
(*Above*) The model of the Dounreay site exhibited by the U.K. Atomic Energy Authority is inspected by the Secretary-General of the United Nations, Mr. Dag Hammarskjöld (holding pamphlets). Also looking at the model are Dr. J. V. Dunworth (*second on right of Mr. Hammarskjöld*), head of the Reactor Physics Division at Harwell and Mr. Eric Underwood, director of A.E.A.'s Public Relations (*on left of Mr. Hammarskjöld*).
(*Right*) It was the discovery of uranium fission which set the scientists directly on the road leading to the release of atomic energy in atomic piles. Appropriately the German delegation was led by Prof. Otto Hahn, who discovered fission, seen here with Sir John Cockcroft, director of Harwell.





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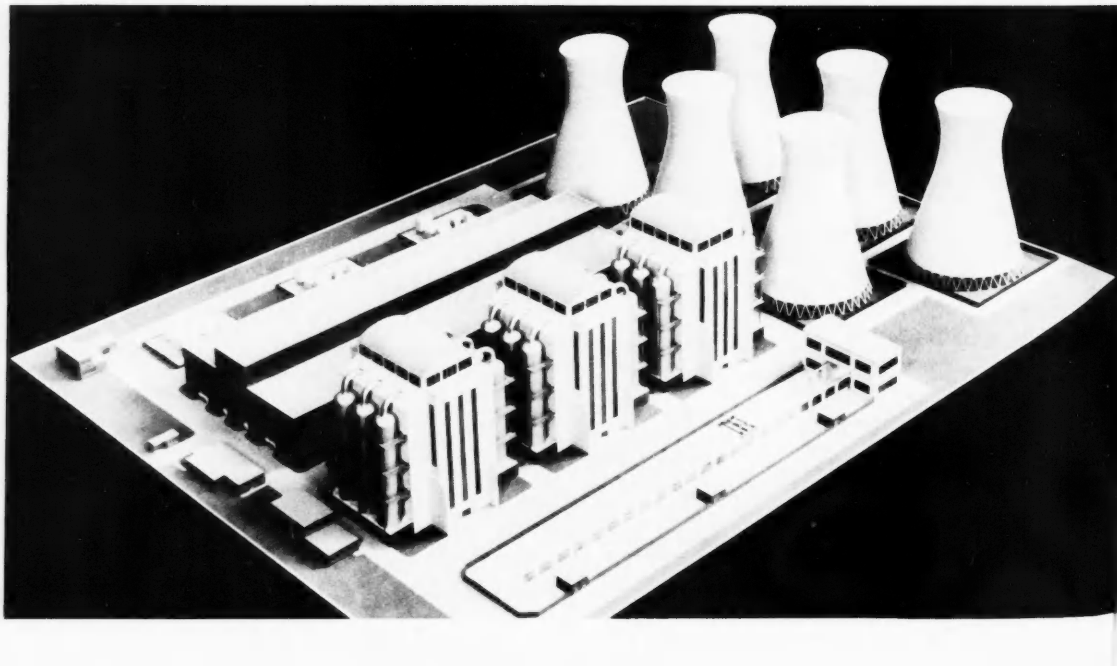
(*Top left*) The British display was generally agreed to be among the finest in the atomic trade fair held in the Palais des Expositions, Geneva's counterpart of London's Olympia. Its centre section, organised by the U.K. Atomic Energy Authority, included a series of brilliant panels designed by James Gardner to tell the story of the researches that led to the harnessing of atomic power. The A.E.A. also showed an excellent large-scale model of Calder Hall, and this model of DIDO, the heavy water reactor at Harwell. In the second section British firms showed instruments that are vital to progress in nuclear research and development. The exhibitors in the third section were industrial firms connected with Britain's atomic power programme; (*below*) G.E.C. exhibited this model of an atomic power station, with its three nuclear reactors (with six heat exchangers apiece). (*Top right*) Many films were shown at Geneva, including the excellent documentary in colour about the building of the Calder Hall power station, which is likely to be generating electricity before the end of 1955. These three frames come from the record film Dr. Zinn used to illustrate his paper about runaway reactors.



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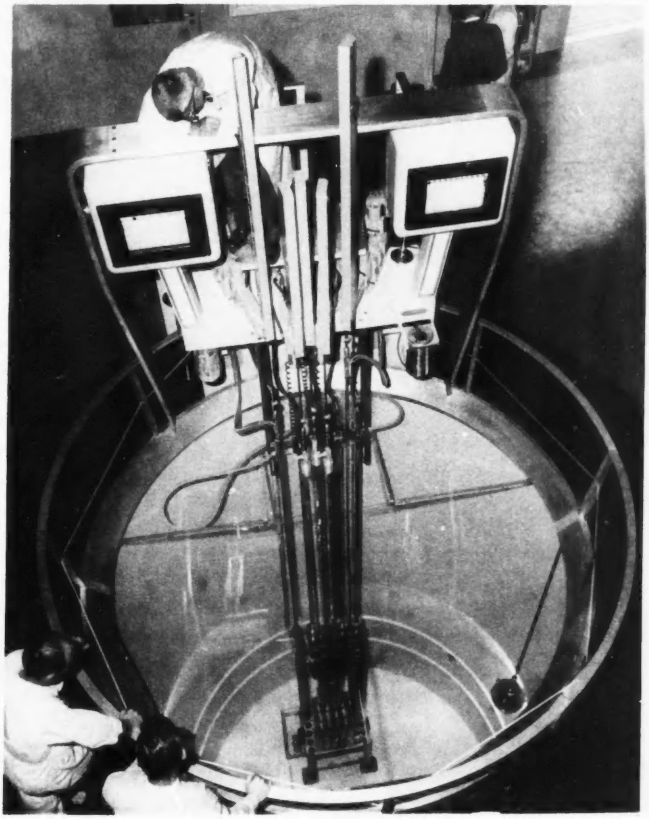
(*Right*) Thousands came to watch the operation of the "swimming pool" reactor which the U.S. Atomic Energy Commission had installed in a chalet erected in the grounds of the Palais des Nations. This reactor designed for research and training purposes cost 350,000 dollars. The active core is composed of enriched uranium, with a U235 content of 20%. The fuel lattice is immersed in the "swimming pool", the water serving as coolant, moderator and radiation shield. Ordinarily the reactor runs at a power level of 10 kilowatts.
(*Bottom right*) Associated Electrical Industries featured the British counterpart of this American reactor. This A.E.I. reactor (costing £75,000 without the uranium) is designed to run at 100 kilowatts continuously: or at a megawatt for 5–10 hours.
(*Bottom left*) English Electric showed their electromagnetic pump designed to pump liquid metals (e.g. sodium) used as the coolant for certain kinds of reactors. Its operating principle is that of a squirrel-cage induction motor in which the pumping fluid is the moving part.



Fermi's team which brought the world's first atomic pile into operation. He spoke about the operation of two U.S. fast reactors. One, built at Los Alamos, was fuelled with plutonium. The other, in the Argonne Laboratory, used U235 enriched to at least 90%.

A model of Russia's first nuclear power station was included among the U.S.S.R. scientific exhibits at the Palais des Nations, and its construction was shown in a film called "First in the World". This 5000-kilowatt unit, which first generated electric power in June 1954, was described by Dr. D. I. Blokhintsev (615), who said it was built "to accumulate technical experience in the construction of power plants" and to provide training for personnel. The fuel charge is 550 kilograms of uranium containing 5% U235. The reactor is graphite-moderated. Heat is taken from the reactor by ordinary water pressurised to prevent boiling. Dr. Blokhintsev said a 100-megawatt station was due to operate within a year. Fuel cost per kilowatt would be greater than in a coal-fired power-station, but less labour would be required to run it: for instance, the workers needed to operate the reactor and steam generators should be two to three times less. He mentioned briefly the possibility of using molybdenum uranium alloys in reactor construction; 9% molybdenum gives a better structural material than ordinary uranium. Evidently, too, Russia has done intensive studies on zirconium alloys.

Runaway Reactors

In the U.S.A. drastic experiments have been made to find out what can happen when homogeneous water-moderated reactors are intentionally allowed to run away. A paper by J. R. Dietrich of the Argonne National Laboratory (481) gave some information about the results so obtained. A film was shown of the total destruction of one reactor in which a power surge was followed by an explosion, brought about by the high steam pressure resulting from the water (the moderator in this reactor) boiling inside the reactor core. This pressure probably exceeded 10,000 lb. per square inch. Fragments of the fuel plates were thrown 200 feet from the reactor site. A careful check was made to trace all the radioactive debris which was scattered about, and this showed that practically all of the reactor fuel could be accounted for within a radius of 350 feet around the site. Momentarily during the explosion a serious "burst" of gamma radiation was recorded half a mile from the reactor, but this fell away rapidly; a very small amount of radiation reached this distance cross-wind. Dr. Dietrich said the explosion effects were comparable to those caused by "a moderate amount of chemical explosion". The heat in the core melted the reactor plates, and quite certainly the nuclear power release stopped very early in the explosion. In less drastic experiments it was established that there is a degree of self-regulation about a runaway pile: the reactivity of the core falls away automatically because of the heat which reduces the density of the moderator and of the fuel. "Under conditions of both boiling and non-boiling operation," said Dr. Dietrich, "the reactor power was self-limiting," but he added that the power surge stopped more rapidly under boiling conditions.

A Dutch team has opened up a new line of possible development for power reactors by substituting a fluidised column of uranium oxide for the conventional reactor fuel elements, and one such experimental pile is now under construction. This project was described (in paper No. 938) by H. de Bruyn and J. J. Went (who is Director of the Physics Department of KEMA, the testing station of the Dutch power industry at Arnhem).

Biological Risks

The biological risks which are inseparable from the age of atomic power were not minimised at this conference, though it is perhaps to be regretted that by the time they came to be discussed the conference had divided up into separate specialised sessions; as many as three sessions were held simultaneously, so that the biologists and medical experts congregated in one hall while the people interested in, say, reactor development were meeting elsewhere and missed what was being said about this very important aspect of the Atomic Age.

One paper (394) showed that Harwell has given much thought to the hazards that would be encountered if an accident occurred to an atomic reactor. Dr. Marley and Dr. Fry of A.E.R.E. said that up to date the "reactor incidents" that have occurred (none apparently in Britain) have not led to the release of much radioactivity into the atmosphere. But the possibility has to be faced that a cloud of radioactive fission products might escape into the atmosphere; this would mean biological risks due (*a*) to the direct effects of beta and gamma radiation, and inhaled radioactive dust; and (*b*) to indirect effects, due to deposition of radioactive matter on crops, drinking water sources, etc. They visualised that if a serious accident occurred in a high-power reactor the spread of accumulated fission products might necessitate the lengthy evacuation of the civil population from a narrow sector extending a mile downwind; temporary evacuation might be necessary out to 3½ miles, and contamination of pastures making cows' milk unsafe could occur up to 12½ miles. The paper ended on an optimistic note, however; the conclusion was that "accidents must necessarily be infrequent and remote siting of reactors should be unnecessary".

Many people thought that the risks of gene mutations arising in the Atomic Age were rather lightly treated by Sir Ernest Rock Carling, who is the Home Office adviser on radiation hazards, in the course of a paper (450) on medical aspects of radiation injury. He said some natural mutations may be attributed to background radiation. Taking the population of an area where the cosmic rays or the radiation from, say, the rocks are more intensive, then the fraction of mutations due to radiation would be increased on the principle that "double the dose rate of radiation doubles the mutation rate". Said Sir Ernest: "Though no investigations have been directly specifically to the point, the Scots and Swedes might well resent any implications of degeneracy"—Scotland and Sweden being countries with areas in which the natural radiation level is above average. He said there was no convincing evidence that families of radiologists are smaller than normal, nor that abnormalities among their children are more frequent. Then came the passage in his speech which gave rise to much controversy both among members of the conference and in the Press. He said: "Whether in a world exposed to a background of seriously harmful level, or subject to occasional very high-level incidence, values would alter so drastically that some form of eugenic compulsion might be accepted or imposed is not at present for consideration. Moreover, in a world contemplating a future in which the expansion of its population may outrange its food supply it is conceivable that diminished fertility and shortening of life-span might not be altogether to be deplored. In so far, however, as a diminution of general intelligence might result, speculation is depressing, but it is to be hoped there may still be "sports" of extremely highly intelligence, who would suffice to leaven the lump. To the non-geneticist it appears that for the benefit of the race as a whole in the future, one mutation which results in an Aristotle, a Leonardo, a Newton, a Gauss, a Pasteur, an Einstein might well outweigh ninety-nine that led to mental defectives."

At discussion time, Prof. A. Gustafsson of Stockholm University lost no time in repudiating this last suggestion of Sir Ernest's. He said that a mutation involving only a single gene could bring about idiocy: that type of mutation had no bearing on the emergence of genius, which represented a unique combination involving all the genes.

Another passage in Sir Ernest's speech dealing with a different matter deserves to be quoted since it emphasises the good safety record of atomic establishments. He said that accidents are in fact extremely few and it is of interest that the standard of conduct inculcated for observance of radiation safety rules is reflected in a rate of ordinary industrial accidents lower than that in other comparable establishments and factories.

Dr. J. F. Loutit, director of the Medical Research Council's radiobiological research unit at Harwell,

said that sensitivity to radiation is correlated with the degree of evolutionary complexity, so that man and his domesticated animals would be among the first to suffer from over-exposure to ionising radiation. "If we take sufficient care radiobiologically to look after man, with few exceptions the rest of nature will take care of itself." Dr. Loutit was speaking about the importance of experimental work with animals (e.g. mice) to discover the effects of radiation on the body and thus to get ideas which can be applied for the better protection of humans. On the genetic aspect, he said "We know virtually nothing about the effects of radiation on the genetics of man". Relevant genetic information had come from experiments with animals, plants, bacteria and viruses, and the facts common to all of them could fairly safely be applied to man. A dose of x-rays of about 50 roentgen doubles the spontaneous mutation rate. "We can but hope that we are not in error in accepting 50 roentgen as a doubling dose for man," he remarked.

Dr. W. L. Russell of Oak Ridge (Paper No. 235) gave results of work he had done on the mutation rate in mice (mainly males) irradiated with x-rays. This works out at about fifteen times greater than in *Drosophila*, the favourite experimental animal for this kind of experiment. He mentioned that another scientist, Dr. Muller, obtained a comparable figure—of eighteen, in fact. This illustrates Dr. Loutit's point that the higher the animal is in the evolutionary scale, the more sensitive it is to radiation.

Radiation and Plant Breeding

At a Press conference, Prof. Gustafsson of Stockholm said that when working with plants the proportion of useful to negative or deleterious mutations produced by radiation was approximately 1 : 500. This opened up possibilities of "re-making" such crop plants as barley, and already new varieties of barley, mustard, peas, etc. resulting from this technique are being given field trials. The technique was a supplementary aid in plant breeding, not a substitute for standard methods of hybridisation, selection and the artificial production of polyploids. (Further details can be found in the paper, No. 793, on beneficial plant mutations described by the Stockholm University team.)

Dr. W. R. Singleton of the Brookhaven National Laboratory (No. 110) described some of the American results obtained by this method. Pioneer work was carried out shortly after the war by Dr. Gregory of the North Carolina Experimental Station, who succeeded in obtaining new mutant strains of peanuts that showed promise: e.g. they yielded more heavily, were better adapted to mechanical harvesting, and were resistant to fungus disease. It is, he said, imperative to work with large numbers, and cited the 975,000 peanut plants with which Dr. Gregory worked. Dr. Singleton's team did not use Dr. Gregory's method of irradiating the seed. Instead, plants (e.g. of maize) were grown in concentric circles in a field at the centre of which is a cobalt-60 source, giving powerful gamma radiation. The latest cobalt-60 unit (housing a 200-curie source) devised for this work can be made for less than 5000 dollars, and should find use in other parts of the world. Dr. Singleton described some of the useful mutants produced by this method in a variety of plants. To illustrate the somatic mutations (bud sports) that have been obtained he showed a striking coloured slide of a plant of white carnation (variety, White Slim) on which one branch—the result of somatic mutation—carried all red flowers. Cuttings from that branch produced plants with only red flowers.

Radio-isotopes

Several sessions were devoted to the many applications of radio-isotopes. There were two on their use in medicine, two on agricultural applications, and two on physiological and biochemical work with these isotopes.

Harwell has done a great deal to develop industrial uses of radio-isotopes, and British papers to the conference on these matters included one by Dr. H. Seligman (No. 395), who is head of Harwell's Isotope Division, and by two of his team, J. L. Putman and S. Jefferson.

Dr. Seligman mentioned that radio-isotopes were used in the Comet crash investigations. It was thought that kerosene might have leaked out of the fuel tanks and ignited to cause an explosion. A Comet, whose tanks were filled with kerosene rendered radioactive by the addition of an organic compound containing palladium 109, carried out a strenuous aerobatic flight, but afterwards no fuel was found to have leaked out of the tanks. This experiment enabled the experts to exclude the possibility that this might have been a possible reason for the tragedy. He said that one other type of British plane examined in this way had shown spillage from the fuel tanks, and was being modified accordingly. "Static eliminators" based on beta emission were mentioned by J. L. Putman in the August issue of DISCOVERY (p. 325), and Dr. Seligman said that in some factories this device has brought about an increase in output of 20–50% since machines can be run faster because of the much-reduced risk. He spoke of new methods for detecting leaks in pipes, a problem of special interest in Britain since much of our piping is so ancient. (He gave a figure of 50% for the amount of liquid lost by leaks from Glasgow's water pipes.) He explained how gamma-scattering gauges make it possible to detect corrosion in pipes from the outside, and these should be very useful as they make it unnecessary for the periodical shut-down of an industrial plant for the purpose of checking the condition of the piping. The other Harwell paper mentioned above dealt in more detail with the application of radio-isotopes to leakage and hydraulic problems.

The Russians had some surprising results to report from their experiments with carbon-14 in the field of plant physiology. Prof. A. L. Kursanov of the Soviet Academy of Science said he and his associates had discovered a new function of the root system, which consists in the following: the roots absorb carbon dioxide from the soil and bring it to the leaves and other green portions of the plant. It turned out that for synthesis of sugars and other products of assimilation carbon dioxide in the soil can be utilised on a par with the carbon dioxide absorbed from the air, provided there is light. He said this has not only theoretical, but practical value. "It proves the important role humus and the microbiological processes going on in the soil play in supplying carbonic acid to the plants. It also warns against the one-sided understanding of the tasks and possibilities of utilising mineral fertilisers."

"Atoms-For-Peace" Awards for Scientists

At a Press conference presided over by Admiral Strauss the announcement was made that a new kind of scientific award, comparable to the Nobel Prizes, had been endowed by the Ford Motor Company Fund. This endowment, amounting to a million dollars, will provide an annual award of 75,000 dollars. This will go to an individual scientist, inventor or engineer—or to teams or groups—who, in the opinion of a special jury—has made the greatest contribution during the year to the peaceful use of atomic energy. At the same conference the prices were announced at which the U.S. Atomic Energy Commission will sell normal uranium metal and heavy water under the U.S. scheme designed to aid friendly nations in the setting up of research reactors. These prices are respectively 40 dollars per kilogram and 28 dollars per lb. A figure was also given for the charge for uranium enriched to 20% in U235 leased for use in research reactors under the bilateral agreements between the United States and friendly nations for co-operation in the civil uses of atomic energy is 25 dollars per gram of contained U235.

Britain's A.E.A. showed great initiative by flying over a number of the conference delegates who visited Harwell. Nearly 150 visitors representing 32 nations, including the U.S.S.R., were shown round on August 24, and the following day U.S. and Canadian scientists were taken on a "classified" tour of the establishment. A team of British scientists are due to go to Moscow to inspect the Russian counterpart of Harwell following on an official invitation which the Russian delegation gave to Sir John Cockcroft at Geneva.

CHEMOTHERAPY OF PLANT VIRUSES

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At the present time there is no well-established exampie of the practical use of chemicals for the prevention or cure of virus diseases. This is true for both plants and animals, if we exclude the lymphogranuloma-psittacosis group of large animal viruses, which are susceptible to treatment by antibiotics and which are now classed with bacteria.

Strictly, the term "chemotherapy" implies the cure of an established disease by chemical means. In fact, almost all compounds which are known to have some effect on virus development are active only if they are administered before or soon after inoculation of the host with virus. Thus their action might be better described as prophylactic. Although spectacular results have been achieved in the chemotherapy of diseases caused by cellular parasites such as bacteria, protozoa and fungi, many workers have despaired of obtaining effective chemical means for controlling diseases due to viruses. Cellular pathogens, even those which are obligate parasites, have a metabolism of their own which may differ in many respects from that of their hosts. There are thus many possible ways in which compounds could interfere with bacterial growth for example, without affecting the host. Viruses, however, are much more intimately dependent on the host for their reproduction and therefore any compound that interferes with virus development is very likely to affect the host as well.

As an introduction to the problem let us consider briefly what is known about the structure and multiplication of viruses. All viruses that have been adequately examined consist almost entirely of protein and nucleic acid. For two plant viruses and several viruses which parasitise bacteria it has now been established that the nucleic acid is contained within a coat of protein. Thus, for example, the bacterial viruses known as T_2, T_4 and T_6 which infect *Bacterium coli* have a "head" consisting of nucleic acid surrounded by a protein shell. Attached to the head is a "tail" of protein. A great deal is now known about how these viruses multiply. Briefly, the sequence of events appears to be as follows. When a virus preparation is mixed with a culture of susceptible bacteria, the virus particles attach themselves to the surface of the bacterium by the tip of the tail. This process is both rapid and specific. Very soon after attachment the nucleic acid in the head of the virus is injected into the bacterium, apparently through the tail. Almost all of the virus protein remains outside the bacterium and takes no further part in virus development. For about ten minutes after infection no complete infective virus particles can be detected. However, during this period the production of the protein and nucleic acid sub-units of the virus is taking place. After about ten minutes, complete new virus particles begin to appear in the bacterium, and after a further ten minutes or so the bacterial cell bursts liberating 100–300 new virus particles. Thus it seems that nucleic acid from a single infecting particle takes control of the metabolic machinery of the bacterial host cell, and contains the "information" necessary for the production of both the nucleic acid and the protein which is then organised into large numbers of complete virus particles.

No such detailed knowledge exists about the multiplication process for any plant or animal viruses. With two plant viruses there is some evidence suggesting that the main features of the multiplication process may be similar to that described above. One of them is the turnip yellow mosaic virus, and in this the roughly spherical particles are known to consist of a protein shell with nucleic acid inside. The other is the tobacco mosaic virus, and here we have an elongated rod-shaped particle made of protein with a central core of nucleic acid extending down the length of the rod. From plants infected with either of these viruses, two types of virus-like particle can be isolated. One is the virus nucleoprotein which is infective. The other is an apparently identical protein containing no nucleic acid. The particles without nucleic acid are not capable of initiating a new infection, and there is evidence for both viruses that the protein particles are precursors of the complete virus particles. Thus all the evidence points to the vital importance of the nucleic acid for virus multiplication. On the other hand quite extensive chemical alterations can be made to the protein part of tobacco mosaic virus without affecting its infectivity. The virus which arises from infection by such chemically altered virus is like the original normal virus.

There is a growing body of evidence, which we cannot discuss here, suggesting the fundamental importance of nucleic acids as the main chemical carriers of genetic information in all organisms. Nucleic acids are long-chain molecules built up of sugar, phosphoric acid, and a series of four bases. (Five bases instead of four are known to enter into the composition of a few rather exceptional nucleic acids.) The sugar phosphate backbone of the nucleic acid is regular. One base is attached to each sugar (Fig. 1), and the genetic information is thought to be contained in the sequence of bases in the chain. There are two general types of nucleic acid: *deoxyribonucleic acid* (DNA, for short) in which the sugar is *2-deoxy*-ribose, and ribonucleic acid (RNA) in which the sugar is ribose. Most cells contain both DNA and RNA. The DNA is present in the nucleus, and is considered to be the main carrier of genetic information in cellular organisms. (The structure and biological role of DNA was discussed by F. H. C. Crick in a recent article in this journal; see DISCOVERY, 1954, vol. 15, pp. 12–17.) RNA, on the other hand, is found in both the nucleus and the cytoplasm. Bacterial viruses are known to contain only DNA, whereas the plant viruses and most animal viruses so far examined appear to contain only RNA. However, Vaccinia virus and insect viruses contain DNA.

If nucleic acids are the most important part of viruses, and the bases the most important part of nucleic acids,

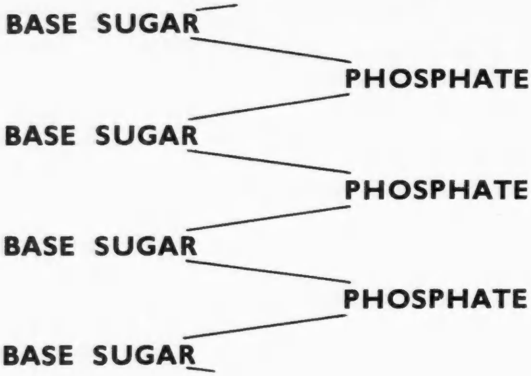


FIG. 1. Diagrammatic representation of part of a nucleic acid chain.

it seems reasonable to look for virus inhibitory agents among synthetic analogues of those natural bases. It has been discovered that several such compounds possess some activity against plant viruses. One of the most interesting so far studied in this connexion is 8-azaguanine. This compound is a synthetic analogue of the natural nucleic acid base called *guanine*, in which a nitrogen atom replaces a carbon at position 8 (Fig. 2). When sprayed on plants up to one or two days after inoculation solutions of 8-azaguanine have a quite marked effect on the spread of virus within the plant and on the development of disease symptoms. Of the viruses we have so far tested, the compound is most active against lucerne mosaic and cucumber mosaic viruses. In tobacco plants, lucerne mosaic virus normally produces local lesions which take the form of straw-coloured concentric rings of necrotic tissue around each point of infection in the inoculated leaf. When the virus moves out of the inoculated leaf into other parts of the plant (such movement within the plant we term "systemic movement") it causes a severe necrosis and collapse of the leaves. In plants treated with 8-azaguanine the development of typical local lesions may be completely suppressed (Fig. 3*a*), and in such leaves there is a very marked reduction in the amount of virus produced. Systemic movement of the virus away from the inoculated leaf may never occur in plants treated with 8-azaguanine, and such plants remain virtually free of virus indefinitely unless they are re-inoculated.

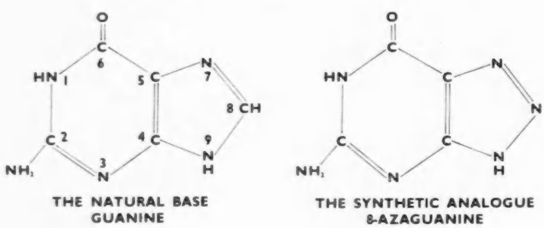


FIG. 2. Guanine and 8-azaguanine.

Inoculation of tobacco plants (of the species *Nicotiana glutinosa*) with cucumber mosaic virus leads to the appearance of a variety of symptoms depending on the strain of virus. With the strain illustrated in Fig. 3*b* the virus causes a bright yellow mottling of the leaves and severe stunting of the plant as a whole. When plants are sprayed with 8-azaguanine beginning not later than about two days after inoculation, the virus may never move systemically out of the inoculated leaf. Moreover, such plants remain free of symptoms of the disease indefinitely unless they are re-inoculated.

With these two particular viruses the compound is effective at concentrations which cause little damage to the host plant, and in most experiments systemic spread of the viruses through the plant was completely prevented. However, once such systemic movement did begin no amount of treatment could check its spread.

With most of the other plant viruses so far tested, 8-azaguanine has very little effect. One of the most useful viruses for experimental work is tobacco mosaic virus, and with this, 8-azaguanine does cause some delay in the systemic movement and in the production of virus (Fig. 4).

The inhibitory effect of 8-azaguanine can be annulled by simultaneous application of the normal base guanine, or various natural related compounds such as adenine and hypoxanthine. However, such observations can tell us very little about how the inhibitory compound acts.

Since 8-azaguanine is so closely related chemically to guanine, it was thought possible that the analogue might be built into the virus nucleic acid replacing some of the normal base. With tobacco mosaic virus this possibility could be tested since the virus is stable and can be isolated from plants in quantity.

Tobacco plants inoculated with tobacco mosaic virus were sprayed with 8-azaguanine every two or three days and harvested fourteen days after inoculation. Virus was isolated by salt precipitation from the treated plants and from untreated controls. The virus was then disrupted by heating and a preparation of the nucleic acid obtained. The nucleic acid preparations were treated with alkali which degrades RNA down to its constituent nucleotides*. The mixture of nucleotides obtained after digestion with alkali were separated, identified and estimated by the microanalytical methods developed by Markham and Smith. From normal virus only the nucleotides of four bases—adenine, guanine, cytosine and uracil—were found. In digested nucleic acid from virus from plants treated with 8-azaguanine a fifth kind of nucleotide was found containing 8-azaguanine. By making a balance sheet of the relative amounts of the various bases present it could be shown that about 3% of the guanine present in normal virus was replaced by 8-azaguanine.

A similar situation has been found by Dunn and Smith for the bacterial virus T_2 grown on its host *Bacterium coli* in the presence of the compound called

* A nucleotide is a unit consisting of a base linked to a sugar and phosphoric acid: thus, base-sugar-phosphoric acid. Nucleotides can be considered as the subunits of nucleic acids.

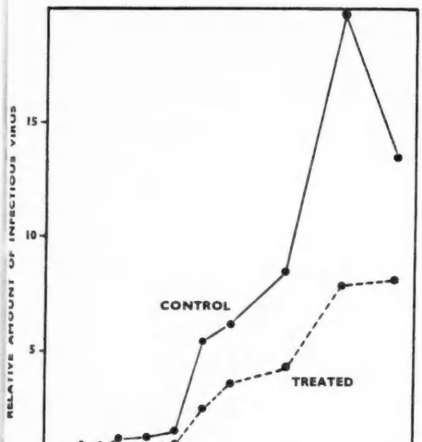
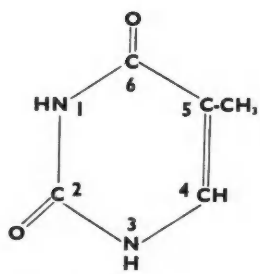


FIG. 3*a* (*above left*). Tobacco leaves inoculated with lucerne mosaic virus. Untreated leaf (*top*) shows typical "ringspot" local lesions at points of infection. The bottom leaf was sprayed with a solution of 8-azaguanine (about 0·1%) 24 hours after inoculation.

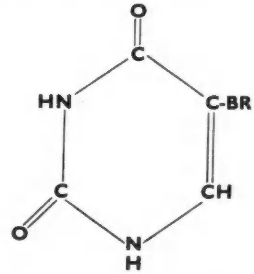
FIG. 3*b* (*above*). *Nicotiana glutinosa* plants inoculated with a stunting strain of cucumber mosaic virus. Untreated control plants are in the front row. In the second row are plants treated with 8-azaguanine for the first two weeks after inoculation. (*Photo by S. Frey.*)

FIG. 4 (*bottom left*). Effect of 8-azaguanine treatment on the production of tobacco mosaic virus in inoculated tobacco leaves.

FIG. 5 (*below*). The chemical structure of thymine and 5-bromouracil.



THE NATURAL BASE THYMINE



THE SYNTHETIC ANALOGUE 5-BROMOURACIL

TABLE 1. INFECTIVITY OF VIRUSES CONTAINING UNNATURAL BASES

Virus	Analogue	% normal base replaced	Infectivity as % of normal
Tobacco mosaic	8-azaguanine	3%	50%
Turnip yellow mosaic	8-azaguanine	< 1%	40%
T_2 bacterial virus	5-bromouracil	79%	30%

5-bromouracil. This substance is an analogue of the natural base thymine, in which a bromine atom replaces the methyl group at position 5 (Fig. 5). In some experiments up to 80% of the thymine in the virus was replaced by the analogue.

The question now arises as to what effect the incorporation of these unnatural compounds has on the biological activity of the virus. The biological activity we can measure is whether or not particles can initiate a new infection. Infectivity is measured by inoculating a susceptible host under appropriate conditions with the virus preparation and then counting the number of centres of infection which develop. Preparations of normal virus and of virus containing an analogue were equalised with respect to concentrations of virus nucleic acid. The preparations were then compared for numbers of infective particles present. In all cases the preparations of virus containing an analogue were less infective than normal virus. Table 1 summarises the information so far available on this point. The most satisfying explanation for these results would be that the non-infective virus particles are normal in all respects except that they contain a certain number of molecules of the unnatural base in their nucleic acid, and that such nucleic acid is unable to initiate a new cycle of virus multiplication; in other words, the chemical alteration of the nucleic acid brought about by the presence of the unnatural base destroys the ability of the nucleic acid to transmit genetic "information". We have no clear idea at present what the significant change in the nucleic acid might be. The elucidation of this problem may give us a closer insight into how nucleic acids function.

The formation of a proportion of "sterile" virus particles in each cycle of virus multiplication would be sufficient to account for the observed delay or inhibition of virus production in host organisms treated with the analogues.

What are the possibilities for practical control of viruses by means of these compounds? On present evidence it seems unlikely that 8-azaguanine itself will be of any value. We know that most of the 8-azaguanine absorbed by plant tissues is rapidly converted to 8-azaxanthine. This compound has no effect on virus development, and thus one of the problems that needs to be solved is how to maintain an adequate concentration of the active compound in the tissues for reasonable periods of time.

In the same kind of way 8-azaguanine is inactivated in animal tissues, and it has been found to have no effect on a number of human and animal viruses. However, it does have a limited effect on certain tumours in mice and in some other animals where it is found to be incorporated into the RNA of the tumour cells.

A more fundamental difficulty is that any compound which is incorporated into virus nucleic acids is likely to be incorporated into the nucleic acids of the host as well. This is known to happen with both 8-azaguanine and 5-bromouracil. However, there are several possible reasons for optimism here. Firstly, in cells in which a virus is multiplying the turnover of virus nucleic acid is probably much greater than that of host nucleic acid and thus there might be preferential incorporation into the virus. Secondly, it is possible that some viruses may contain bases not present in the host nucleic acids. Only one example of this is known. Certain bacterial viruses contain the base 5-hydroxymethylcytosine which is not found in the host, *Bacterium coli*. If analogues could be made which would replace only the base found in the virus, but not in the host, it might be possible to bring about inhibition of the virus, and only the virus. While only one virus-specific base is known so far, it should be recalled that the nucleic acid has been analysed for only about six of some two hundred known plant viruses. Likewise, nothing is known about the base composition of most animal viruses.

As yet there is insufficient information to be able to make firm predictions about what kind of analogue might or might not be incorporated into nucleic acids. Relatively few of the large number of possible analogues of the nucleic acid bases have yet been synthesised and tested. There is also the question of supplying the analogue not as the free base but as the nucleoside (i.e. base+sugar) or as a nucleotide. (A number of nucleotides are possible for each particular base.) These nucleosides and nucleotides might be farther along the route of synthesis of the bases into nucleic acids, and might therefore lead to greater incorporation of the analogue.

So far, we have dealt with only one type of virus-inhibitory compound. However, many substances are known which have an effect on some stage of virus development, but it is only possible to refer to a few of these in this article. There are many natural and synthetic products which inactivate plant viruses *in vitro* and which when applied to the host plant at or before the time of inoculation greatly reduce the number of virus particles which become established. As an illustration, it has been known for many years that applications of milk to plants before inoculation can greatly reduce the number of local lesions produced by tobacco mosaic virus. Recently it has been suggested that milk treatments might be effective for preventing spread of this virus in glasshouse tomato crops. Further work may demonstrate the practical value of such treatments. However, it seems unlikely that substances of this type, which interfere only with the process of initial establishment of the virus in the host, will be of any value in curing plants already infected with a virus. For this purpose we require compounds which will inhibit virus *multiplication* inside the host cell.

With most animal viruses, once the animal has recovered from the disease, no active virus remains in the body. However, once infected with a virus, most plants continue to contain active virus indefinitely, even though the disease symptoms may become milder. In

many vegetatively reproduced crop plants chronic virus infections are a great problem. Where virus-free individuals of an infected variety can be obtained, these can be multiplied up in isolation to provide virus-free stocks, as is now done with many varieties of potato. However, it is often impossible to find virus-free individuals with which to begin building up healthy stocks. Thus some method of curing even a few plants would be most useful. At the present time it seems rather unlikely that chemical treatments will be of much value for diseases of this type, even though quite substantial but temporary plant damage could be tolerated. An effective treatment would have to knock out every one of the many millions of virus particles present throughout the plant. This presents a difficult problem especially with stable viruses which accumulate in cells in large quantities. At Rothamsted and other laboratories it has been found possible to free individual plants of certain viruses by prolonged heat treatment. At the present time this procedure seems to offer more hope for the problem of curing infected plants to give clean nucleus stocks of a variety than does chemical treatment.

A different situation exists where virus infection enters a crop during the growing period. With plants such as citrus and cocoa which are grown for many years and which may be subject to continued reinoculation with viruses by insects, the problem of providing permanent protection against infection by chemical means may be very difficult. With annual crops subject to infection during the growing season, there is a better prospect of providing a useful degree of protection because there is no need to trouble about the permanent prevention of disease development. For example, sugar beet crops are subject to the serious yellows disease which is carried by aphids. Spraying with a non-toxic chemical which delayed disease development for even a few weeks might give a useful increase in yield. It is in crops of this type that we may expect to find the first practical application for chemical treatments in the control of plant viruses.

In the discovery of types of compound effective against cellular pathogens chance has played an important part. Studies on normal metabolism and the mode of action of compounds have been of relatively little assistance so far. However, with the more difficult problem of viruses it may be that information on how compounds have their effects will help towards a solution of the practical problem.

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A PHYSICIST'S VIEWS ON INTERPLANETARY TRAVEL

SIR GEORGE THOMSON, F.R.S.

These opinions of Sir George Thomson, the distinguished British physicist who won the Nobel Prize in 1937, come from his book of scientific prediction entitled "The Foreseeable Future", *which Cambridge University Press is publishing this month. The postscript on p. 429 was written after the book had gone to press.*

The possibilities of travel in space seem at present to appeal to schoolboys more than to scientists. Space ships and Venusians have become a commonplace of adolescent life, more at home in the colourful comics than in the *Proceedings of the Royal Society*. This however is slightly deceptive. There is in fact much more money being spent on problems closely associated with that of leaving this planet than appears to the public. Large sums are being spent by the Great Powers on guided missiles; as so often happens the needs of war are the stimulus to the arts of peace. An appreciable part of the work that is being done on guided missiles is just the kind of thing that would have to be done if it were decided to make a great effort to send projectiles, with or without a crew, away from the pull of the earth's gravitation.

It follows from the principle of action and reaction that to balance or to overcome the force of gravity an aeroplane must give a downward momentum to the air through which it flies at a rate equal (in suitable units) to its weight. This it does by deflecting the air downwards by means of its wings. Every aeroplane is followed by a region of down-wash. The down-wash of the wings of an ordinary aeroplane, for example, affects considerably the behaviour of the tail. But if there is no air to push downwards, how is one to rise? The only possibility compatible with the law of action and reaction is for the body to shoot part of itself downwards and so rise with the rest. In other words, to be a rocket.

Before trying to describe the possibilities of space travel I must digress to explain the principles that govern rockets. They are in fact extremely simple. The upward thrust is equal to the downward momentum per second, and this downward momentum is the product of the mass ejected and the speed of ejection. Now it is obvious that there is a limit to the total amount of mass that can be ejected. Clearly it cannot exceed the original mass of the rocket and indeed must be substantially less, for we must be left with a framework and whatever counts as "pay-load", whether this is an

explosive or a chamber carrying a crew. The rocket is helped by the fact that as the material is shot backwards the rest of the rocket gets lighter. There is a simple relation between the final velocity of the rocket, the velocity of ejection, and the fraction of the mass which remains when the ejection is complete. The designer of a rocket wants his final velocity to be as large as possible and yet to retain as much as possible of the original weight as pay-load. In this respect he will have to compromise, but the nature of the mathematical relation, which is logarithmic,* means that beyond a certain point a small increase in the final speed has to be paid for by a terrible sacrifice in final weight and this is all the worse because one must include in the final weight not only the pay-load but the weight of the casing, the nozzles and all the machinery which may be necessary to operate the rocket, everything in fact but the fuel which can be ejected at a high speed. The designer will do pretty well if he cuts down all these weights to 15% of the original total, and even with only a miserable 5% for the pay-load, this adds up to 20%, leaving 80% for fuel. With this proportion a rocket would reach 1·6 times the velocity at which the fuel is ejected. Clearly the prime object must be to arrange some type of fuel which shoots itself out with the greatest possible velocity.

Moreover, since we envisage a body capable of flight through regions devoid of air, the rocket must carry its oxygen with it if it needs any. In this respect it differs, to its disadvantage, from the jet engine which also derives its thrust from reaction, but gets the oxygen to burn its oil from the air through which it is passing. Obviously one needs some energetic reaction which will produce a great heat and shoot the burnt products out with explosive force. But this is not all; it is not simply a question of energy. Only a part of the energy actually produced by the combustion of the fuel, whether it is solid such as gunpowder, or a mixture of liquids such as alcohol and liquid oxygen used in the German V2, appears as energy of motion in the blast. Considerations of the second law of thermodynamics intervene.

The exact relation is a tolerably complicated one, but if the conditions are chosen favourably the speed of ejection of the burnt products depends mostly on two things: the temperature of burnt gas, and its molecular weight. The higher the temperature and the lower the molecular weight, the greater is the speed. Now the temperature at which one can work is limited not only, or even mainly, by the energy available, but by the risk of melting the container and jet. In the V2 for example, it was necessary to dilute the alcohol with water to prevent this happening. By employing tricks of cooling it is possible indeed to use a flame considerably hotter than the normal melting-point of the metal of which the rocket is made. But there is a practical limit to the extent to which this can be done.

For a given chemical reaction the average molecular weight of the products is of course fixed. In the case of oxygen and alcohol the products are steam and oxides of carbon, mostly the former. The practical velocity appears to be about 2·5 kilometres per second. Fluorine and hydrogen would do considerably better, but the chemical difficulties of dealing with very corrosive fluorine and the even more unpleasant hydrofluoric acid which it would produce, and the physical difficulties of storing liquid hydrogen, are daunting. Nevertheless it may be used, in fact it possibly has already been used. The best published estimate is that it might be possible to reach a velocity of ejection of 4 kilometres per second with something like the present set-up*. Taking the final velocity as 1·6 times the ejecting velocity gives us 6·4 kilometres per second, but the speed with which such a rocket could emerge from the atmosphere would be substantially less, partly because of the resistance of the air, but more because gravity is acting during the process and slowing the rocket down. It might in fact be about 5·4.

Now how does this compare with what would be needed for a flight to the moon? The earth's atmosphere has no definite edge, but yet falls off so rapidly that it is wholly negligible at a height of a few hundred miles. The earth's gravitational attraction also diminishes with distance but much more slowly. At a height of 1650 miles the pull is still half that on the earth and even 4000 miles from the surface it is a quarter of the normal value. Nevertheless it does fall off, and at astronomical distances, even the moderately astronomical distance of the moon, it is almost negligible. A projectile shot from the earth at sufficient speed will escape completely and proceed on its path through space. It will be deflected by other heavenly bodies, if it happens to pass near them, and in certain special and rather rare circumstances may be captured by one and become a satellite of it. The speed for this escape from the earth is 11·2 kilometres per second and the very slightly smaller speed of 11·1 would carry a projectile, if it were suitably aimed, to a point at which the attractions of the earth and the moon balance and from which it would "fall" towards the moon. This is a good deal higher speed even than the hoped-for 5·4 kilometres, but before considering the possibilities of closing the gap there is another smaller velocity characteristic of the earth which is of considerable interest, namely the speed with which a body would have to be shot in a horizontal direction in order to travel round the earth for ever and ever—forgetting for the moment the existence of the air and the resistance which it would impose. It is not very difficult to see how it comes about that there is such a velocity. The horizontally moving object, moving that is at right angles to the radius of the earth, will be perpetually falling and attempting to approach the earth; but the earth is, by its curvature, as perpetually receding from it and at a certain speed of the body the two curvatures will match and the body will follow the earth indefinitely round. This value at the surface of the earth is 7·9 kilometres per second†. At a height where the experiment becomes

* The final velocity is equal to the velocity of ejection multiplied by $\log_e \left(\frac{mo}{m}\right)$, where *mo* is the initial, and *m* the final mass.

* *Interplanetary Flight*, Clarke, p. 27.

† The orbital velocity is equal to the velocity of escape divided by $\sqrt{2}$.

practical, i.e. where the resistance of the air can be neglected, the velocity becomes somewhat smaller, but if you had to do the experiment by shooting a body up from the earth and then making it bend round, the loss of velocity in leaving the earth would be greater than the difference, and you would require rather more total velocity than 7·9, though not very much. This orbital velocity represents so to speak, a possible first stage in escape for a body moving in such an orbit. The velocity which must be added for it to escape completely is the difference between 11·2 and 7·9, i.e. 3·3 kilometres per second. If in fact such a body had some rocket power left and could accelerate its orbit would gradually draw away from the earth in a spiral, for the attraction of the earth would have less time to act as it moved through, say, 1° of latitude, and so would no longer be able to bend it into a circle of radius equal to its distance from the centre of the earth. If acceleration is continued long enough, it will spiral right away from the earth and become a freely moving body.

But even this 7·9 kilometres per second is above the velocity which can be obtained with present material in the way in which we have suggested. Is there no way out of the difficulty? The first and most obvious is to use a two-stage rocket. This is in fact a small rocket riding on the back of a large one. When the large one has exhausted its fuel the small one starts up, leaving the case of the large one behind and adding its velocity to that which the large one had previously acquired. In this way one can double the velocity, but at a serious expense in "pay-load". Thus if the first rocket has a pay-load of 5%, which will in fact be the second rocket, and this in turn has a pay-load of 5%, the original device will weigh 400 times as much as the final pay-load; a very uneconomical process, but it would enable you to land something with the speed needed to carry it in a closed orbit. Allowing for all the various kinds of inefficiencies, it would not get you quite clear of the earth's attraction. That could be done no doubt by yet another stage, multiplying the total weight for the same pay-load by yet another factor of 20 and requiring 8000 tons to give 1 ton the freedom of space. It is doubtful if such a large rocket would be practical, though von Braun, the designer of the V2, has seriously proposed one.

There are two considerations which may help to resolve this difficulty, perhaps separately or perhaps in conjunction: the use of nuclear energy, and the possibility of using a space platform, orbiting around the earth in the way we have described, from which the actual voyage could start.

You will remember that the speed of ejection of the materials of the rocket on which all this depends is increased by reducing the molecular weight. Now as long as we use chemical reactions, the end-product and its molecular weight is not fully at our disposal, though naturally one chooses a reaction which gives as light a molecular weight as one can. If, however, one can supply heat by means other than chemical, one can use substances of a very low molecular weight, hydrogen or helium, and so gain a very substantial advantage. A nuclear reactor supplies energy in the form of heat and a reactor of the so-called fast kind is not necessarily a very heavy or bulky object. Theoretically, at least, there seems no reason why it should not be used to heat hydrogen up to a very high temperature. There are, however, serious practical difficulties. The plutonium or U235 that would be used would melt at the temperature one would need. But this does not in itself prevent the nuclear reaction from continuing. The difficulties are certainly serious, but they are probably not insuperable, and one might hope, perhaps, to reach velocities of ejection near 10 kilometres per second. With such a rocket it should be possible to reach an orbit with a single stage, even if it were not possible to escape completely.

It would be better still, of course, if it were possible to use for our jet particles moving with the velocities which are acquired in the process of nuclear fission, or which can be manufactured, though in relatively small numbers, in the atom-smashing machines. There are very serious difficulties even here. One of them is that while from the point of view of momentum the faster one can eject particles the better, from the point of view of energy it is just the reverse. If you want to save mass and have plenty of energy you push the things out fast, while if you do not mind about the mass but care more about energy you push more mass out more slowly. Now it is true that the nuclear reaction might well supply all the energy that would be required even to accelerate the rocket by particles of the highest velocity, but it would certainly be impossible to direct this energy only in the desired direction. If a nuclear reaction were allowed to go on at the rate you would need, so much energy would be generated that the whole rocket would melt—and indeed would behave rather like an atomic bomb. There may be a way out of this difficulty. In raising the rocket from the ground to an orbit round the earth, it is necessary to do so at top speed, for gravity is acting all the time and opposing the increase in velocity. But if the rocket is raised to a height clear of the atmosphere and turned so as to be moving horizontally, gravity no longer reduces its speed, but merely bends the path round to fit the earth. In these circumstances rapid acceleration is not necessary and there seems no reason in principle why the particles should not be ejected with velocities a thousand times greater than those used at present.

There are indeed serious practical difficulties. One way of making a very fast jet would be to install a machine for accelerating ions, but if it at all resembles those already in use it would be enormously heavy in proportion to the mass it ejects. Theoretically, if nuclear fission can be made to proceed on the surface only of a block of plutonium, and those fission particles that were moving outwards were allowed themselves to form the rocket jet, one could do without any other machinery. But this very simple solution seems quite impracticable because of the great discrepancies between the penetrating powers of the neutrons which are producing the reaction, and the fission particles which it is desired to use. Only a negligibly small proportion of the fission

Experts on space travel believe that the only method using chemical propellents that would be capable of taking an expedition to the moon would involve the refuelling of the space ship at an earth-satellite station. Dr. Wernher von Braun has put forward one ambitious project that calls for the construction of a lunar space ship on a satellite circling in an orbit 1075 miles from the earth; in this photograph he is seen explaining the model of this space ship. This would be 160 feet in length and would require thirty rocket motors having a total thrust of 407 tons. These motors would consume 4300 tons of hydrazine and nitric acid. The sphere at the top of the rocket model represents the crew chamber which would be about 30 feet in diameter and designed to accommodate twenty-five men. Von Braun envisages using three of these ships to carry an expedition to the moon.

particles produced would escape as desired. A better chance would be to use the radioactive fission products, which are a by-product of nuclear energy piles and give off beta rays (fast electrons). These have a relatively long range, and if the material were spread out thin over a large surface nearly half of them could escape. Electrons are too light to form the material for an efficient jet, but it would not be very difficult to use their energy to generate an electric field which could be used to accelerate heavier charged bodies, either atoms or clusters of atoms, which could provide the actual material of the jet. Positively-charged particles would be used so that they could compensate for the loss of the negatively charged beta rays. The rocket must not lose or gain a net charge for any length of time, or it will build up an enormous electrical potential stopping the process; but it is not, in theory at least, difficult to adjust the balance by a low-power leak of either sign.

Whatever method is, in fact, adopted, the slow acceleration of a rocket once it has reached an orbit outside the atmosphere seems not to conflict with any physical principle. Nuclear reactions can provide ample energy, and since it can be applied slowly there need be no difficulty about over-heating, while with such a high-speed jet the amount of actual material required is not prohibitive.

Such a rocket could cruise about the solar system and make orbits round the moon and planets. To land when it returns to earth it could have wings and gradually lose speed by the resistance exerted by the upper parts of the atmosphere, finishing its course as an ordinary glider. A landing of this kind is a manœuvre which needs judgment and accuracy. If carried out clumsily the machine may be burnt up by the heat produced by its passage through dense air. The extremely high speed acquired in approaching the earth will have to be destroyed very gradually in the low-density layers before the pilot dares to venture lower.

To land on the moon, still more on a planet, is a serious undertaking. Unless the planet has an adequate atmosphere, which the moon certainly has not, the landing will require the use of a downward blast of rocket to check the velocity of fall; in fact the process is that of take-off reversed, as seen in a cinema film run backwards. This retardation, because it needs a large thrust, can only be done by particles of thermal velocities and will necessarily cost a lot of jettisoned material. The same, of course, will be true for the take-off. Thus, to reach a planet, without atmosphere, of the size of the earth, land on it and get back would require an ability of accelerating rapidly three times that required to reach the earth's orbital velocity. That is rocketry enough to give a velocity $3 \times 7{\cdot}9 = 23{\cdot}7$ kilometres per second. The moon is very much smaller than the earth and Mars somewhat smaller. The figures for these are: Moon 11·1 kilometres per second, Mars 16·5 kilometres per second. These are high figures. Still, one cannot help feeling that both can be attained by developments on the lines we have indicated. Improved materials will be an enormous help by reducing structure weights.

A project is being pressed in the United States by von Braun, the designer of the V2, of establishing a permanent satellite round the earth, which would act as a half-way stage for flights to the planets. It would have to be assembled in place from relatively small components shot up by rockets in the way that has just been described. These components would move round in similar orbits if their velocities were correctly adjusted, and it is considered that they could be directed pretty close together and finally united into a structure. This would, of course, involve men working in the vacuum in suits containing air near the normal atmospheric pressure. The design of such suits presents problems, but some have been designed to make possible the escape of pilots from aeroplanes flying at an altitude at which life would be impossible, and, though cumbrous, they seem to allow reasonable freedom of

movement. It must be remembered that once clear of the earth's atmosphere, whether in an orbit or not, there would be no sensation of weight. Nor would there be any tendency for a body, human or otherwise, accidentally detached from another body, either to move farther away or to return. It is extremely doubtful what the physiological effects will be, for no one has experienced such a state for more than a very few seconds. Even a man falling in a delayed parachute drop soon goes so fast that the resistance of the air prevents his free acceleration, while once his parachute has opened and his speed has steadied, he feels his normal weight despite his downward motion. Experiments on animals carried up in rockets in the United States suggest that the effect is not serious, but here again the times were relatively small and troubles such as exaggerated seasickness may be one of the most serious in space navigation. If it were possible to complete von Braun's space station, it would be given a kind of artificial gravity by making it in the shape of an immense tyre and spinning it so that centrifugal force would simulate gravity and tend to drive everything inside the tyre to rest against its outer rim. It is hard to see how one could do anything satisfactory on these lines for the much smaller vessels, which alone could journey to the moon or planets.

The conception of a satellite station should not be dismissed as wholly fantastic, though it bristles with technical difficulties. What I personally regard as absurd is the emphasis von Braun lays on the satellite station as an instrument of war, to be used for observation and presumably to direct guided missiles. Unless one country had such an enormous technical lead over the others that it would not need such an aid, I cannot see the least prospect of establishing a station that would not be destroyed almost at once by guided missiles from below, which would be far easier to construct than the station itself.

One possible difficulty of interplanetary flight is the danger from meteorites. Meteorites even of the size of a rifle bullet are extremely rare, and if they were the only danger the space traveller would be far safer than in Piccadilly, but there are vast numbers of quite tiny meteorites of the size of a pin's head, or less, which might do serious damage to the skin of the vessel and produce leaks of the air that it must contain. It has been suggested that the danger of this could be almost eliminated by a thin outer covering, an inch or two away from the airtight material. The meteorite would vaporise a small portion of this shield and itself as well.

It is obvious from this short account that there are many difficulties to interplanetary travel besides the obvious one of getting off the earth, but there seems to be nothing that is really fundamental and one cannot help feeling confident that in the next 50 or 100 years the ingenuity of engineers will have overcome them.

It is another matter if one wants to get to even the nearest star, Proxima Centauri 4·3 light years away. While nothing can go faster than light it is now possible to accelerate electrons to within a very small fraction of that speed and even protons to something quite comparable. At speeds very close indeed to that of light odd things happen with time, and ordinary chemical and biological processes might be expected to go much more slowly.* To make any use of this would require a new physical discovery, for change in time-scale involves proportional change in mass as well, and therefore enormous added energy. No nuclear reaction conceived at present involves the destruction of more than one part in 130 of the reacting masses, which is what one gets when four hydrogen nuclei condense to form one of helium. To give even one-half the velocity of light requires on the most favourable calculation a mass-ratio of 83, in other words 82 parts in 83 of the original rocket must be fuel and only one part in 83 structure and pay-load, a state of things which it would be difficult to achieve even with a multi-stage rocket. But at half the velocity of light the change in time-scale is only 15% and the time to Proxima Centauri and back would be $4{\cdot}3 \times 2 \times 2$ or 17·2 years as measured from the earth, and only 2·6 years less from the point of view of the crew of the rocket. This seems a small prize for all the discomfort and risk. Whatever the attractions of interstellar travel perpetual youth is hardly likely to be an important one. Apart, however, from the time it would take to get anywhere worth while, escape from the solar system is not all that difficult—not much harder than a landing and return from Mars.

Is there a way over the time difficulty? Perhaps, if there are such things as negative protons, and one could make and handle them in bulk—but this is not the foreseeable future. A visit to the stars is not imminent but we may well be nearer to it in time than we are to Pekin man.

* The bearing of the relativistic contraction of time on this problem has been questioned, since it leads to an apparent paradox, but the best opinion is that the contraction would occur and that the returning astronaut would, in fact, find that time had gone more rapidly on the earth than on his space ship.

POSTSCRIPT

Since the above was written an announcement has been made by the U.S. Government that they propose to establish a "satellite" moving in a semi-permanent orbit round the earth. The U.S.S.R. has stated that they have a similar project. These satellites would be quite small bodies containing instruments whose readings would be signalled back to the earth giving information about conditions at a place effectively outside the earth's atmosphere. From the scientific point of view this is an extension of work that has been done in the U.S.A. with rockets of the modified V_2 type. It can give valuable information about both the cosmic rays and the sun's radiation before they have been appreciably changed by going through the earth's atmosphere. Apparently the height proposed is one at which there will still be an extremely tenuous atmosphere so that the satellite will be very gradually retarded, falling eventually into the denser atmosphere where it will be burnt up. Apart from the purely scientific interest, the satellite is exciting as a first stage to space travel. The process of launching it should give very valuable experience, and the data on radiation and on meteorites will be needed for the next stage whatever it is. But there is quite a long step between a satellite a couple of feet across and one which could serve as a station or refuelling point for a voyage to the moon!

SOME LESSER KNOWN SOURCES

E. J. OFFORD

Technical Information and Documents Unit, Department of Scientific and Industrial Research

The two articles that appeared in the June and July 1955 issues of DISCOVERY discussed many sources of published information, including directories, technical and scientific journals, and reference books. This article will describe the less accessible material frequently referred to as *unpublished* and *semi-published reports*, a source which is sometimes more rewarding to the searcher than published documents. It is a more difficult source to tap, and guidance given here will enable the reader to find much of the unpublished material which is available in this country.

Firstly, it is important to define clearly what is meant by "unpublished" material. Broadly speaking, the writer regards any document that is not generally known or easily available in the United Kingdom as an "unpublished report" although, if the document happens to be a foreign publication, it may be widely advertised and sold in the country of origin. Thus many United States Government Research Reports which are on sale in the United States are included in the writer's "unpublished report" category, since they are largely unknown in British industrial firms and other organisations in this country, although these documents are freely available in the United Kingdom through the Department of Scientific and Industrial Research. Such reports are not all widely known in this country, even to professional Technical Information Officers.

The DSIR has realised the value of this kind of material, and for the past few years has made a considerable effort towards its collection for the use of British industry. So far as the author is aware, there is no other source in the United Kingdom from which the various types of reports described below can be obtained.

The Technical Information and Documents Unit (TIDU) was formed in 1947 to disseminate the published and unpublished reports on German industry. Considerable use is still being made by industry of this German material. TIDU became part of the Intelligence Division of DSIR in 1951. Subsequently TIDU widened its field to include other types of reports of British and foreign origin. The following are some of the main series of reports in this category:

U.S. Government Research Reports, Publication Board series. These are disseminated by the Office of Technical Services (OTS), which is part of the U.S. Department of Commerce, Washington, D.C. The Office of Technical Services is a clearing-house for technical information of use to American industry. These "PB" reports represent one of the world's largest collections of non-confidential technical information, and there are now some 250,000 reports in this series. A monthly bibliography of U.S. Government Research Reports is issued by OTS. Many of these are of local interest; others cover such broad subjects as Agriculture and Medicine. TIDU therefore selects about 100 reports each month for dissemination to British industry. These reports are collected from civil and military agencies of the U.S. Government (which sponsors much research in American universities) research institutions and firms, and they cover a very wide scientific and industrial field.

Canadian National Research Council. A series of reports known as "TIS" reports are issued by the Technical Information Service of the Canadian Research Council. They are prepared in response to the demand from Canadian industry for such information. Some fifty titles have so far been issued dealing with such subjects as: spot welding; planning a grey iron foundry; casting of metals in permanent moulds; "soapless" soaps. They all include a bibliography of information readily available in the published literature.

U.S. Bureau of Labor Statistics (BLS) Reports series. These are case study data reports relating to industrial productivity. These data have been collected from manufacturers and individuals in a particular industry, trade associations and labour unions. The reports include data on man-hour output, factory operations, production methods, managerial processes and machinery. Over eighty reports are already available.

Information Reports (IR's). This series arose out of one of the Organisation for European Economic Co-operation projects which provides for a "Question and Answer" service between the member countries. Technical questions put by one OEEC country to the others gave rise to reports on the subject, and it was decided that the most interesting questions and answers should be duplicated and circulated in the other countries participating in the OEEC schemes for the benefit of industry. As can be imagined, these cover a very wide field, the titles of six selected at random are as follows:

"Manufacture of gypsum plaster."
"Production of shortening for bakers and confectioners."
"Automation in American industrial plants."
"Wood wool production."
"Productivity in the plywood industry."
"Factors determining the method of heating steel for die forgings."

In these reports, a description of the process is followed by a bibliography of published material available on the subject.

Unpublished Reports of British Origin. So far the material described has been of U.S. or Canadian origin. There is not so much available from U.K. sources, but some unpublished reports are prepared by DSIR from time to time. For instance, during the sulphur shortage of 1952 a report was drawn up which revealed known sources of alternative materials which could be used for sulphur production. More recently, a review was

prepared on the production and utilisation of selenium.

Other Government departments also produce this type of material. One regular source is the Atomic Energy Research Establishment, and although many of the reports coming from this source are published and sold through H.M. Stationery Office there still remains a fair number which are disseminated by TIDU. However, it is not worth while to list the reports of British origin as they amount to not more than a small proportion of the total dealt with.

BIBLIOGRAPHIES

Another valuable source of technical information on a given subject is, of course, the bibliographies which are issued by a number of organisations. DSIR has insufficient staff for the preparation of many of these, but attention is drawn to the following examples of DSIR bibliographies:

Bibliography of Industrial Drying. This published work, prepared by the DSIR is obtainable only from TIDU. It covers the period from 1924 to 1950, and consists of some 800 pages containing over 4000 references.

Bibliography on Mixing of Pastes, Thick Liquids and Slurries. A stencilled list, prepared by the DSIR, containing 14 pages and about 150 references; copies can be obtained free on request to TIDU.

Select Bibliography of Published References to the Application of Ultrasonics. Issued by the DSIR, it contains 24 pages and about 300 references; stencilled copies are obtainable from TIDU.

There are other sources of bibliographies such as those prepared by libraries and industrial organisations which can be made available to inquirers through TIDU. Typical examples are:

E.M.I. Technical Library Bibliography No. 1. "Magnetic Amplifiers": this covers all aspects of the magnetic amplifier or transductor, including fundamentals, design, construction and applications.

Select Bibliography of Shell-moulding Practice. No. 61 in the series of research bibliographies compiled and published from time to time by Sheffield City Library on subjects of interest to Sheffield trade and industry.

U.S. Department of Commerce: O.T.S. Catalogues of Technical Reports. These bibliographies cover a wide variety of subjects. So far about 400 have been prepared, and TIDU holds a complete set of these catalogues.

Bibliography of Industrial Diamond Applications. This is issued monthly by the Industrial Diamond Information Bureau and is available free of charge to those interested; requests for copies should be sent direct to the Bureau at 32–4 Holborn Viaduct, London, E.C.1.

The bibliographies mentioned above serve to indicate the availability and wide range of these very useful documents.

RUSSIAN TECHNICAL LITERATURE

In 1949 the DSIR launched a scheme to make known the nature of Russian journals, and to make more generally available translations of articles of interest contained in them. About 130 journals are scanned by operating agencies and a monthly list of translated titles is issued by the DSIR. If a translation of an article is commissioned by two firms or individuals, the DSIR will pay one-third of the translation cost. Of course, the greater the number of requests received for the translation of any one article the less the cost to the individual. The DSIR always contribute one share.

OEEC DOCUMENTS EXCHANGE

A scheme for the exchange of scientific and technical literature between OEEC countries came into operation on January 1, 1950. In the United Kingdom TIDU is the clearing-house for this material. Although much of the material received from foreign countries under this scheme is in the form of copies of published journals, it is doubtful whether some of these are well known in this country. One barrier to the greater use of this material is the language difficulty. One set of these exchange documents is kept in TIDU for reference purposes; others are sent to the Science Museum Library and Patent Office Library in London, the Mitchell Library in Glasgow and the Sheffield City Library.

UK TECHNICAL DIGESTS

In March 1954 the DSIR commenced the distribution of technical digests prepared from articles in British periodicals. The broad intention of these digests is to assist productivity by introducing an idea into a field it would not be likely to reach if it were confined to one publication—in other words, a "cross feeding" of ideas. These digests are distributed monthly to trade associations and other organisations which are prepared to give them further distribution amongst their members. Requests from individual firms are also accepted if they are unable to obtain the digests through a trade or other organisation.

EPA TECHNICAL DIGESTS

This is a new project fostered by the European Productivity Agency, Paris, which comes under OEEC. Over 1000 European and American journals are surveyed and from them a selection is made of articles describing processes, methods, apparatus or materials which could be applied fairly quickly and easily in industry to increase productivity and digests of these are prepared. The digests are in English and are designed to give engineers and technicians potentially useful information which they may not otherwise receive. Here again, distribution in this country is undertaken by TIDU and interested firms or organisations can apply for copies for which there is no charge.

DISSEMINATING THE INFORMATION

In conclusion, a brief description of the way in which TIDU disseminates the material it receives may be of interest. We have a mailing list of firms, individuals, and organisations interested in receiving details of reports which we hold. As the reports come in they are summarised and the summaries distributed on a selective basis to those who have indicated an interest in the

subject of the report. If the summary deals with a report which is considered of interest the recipient can borrow the report for two or three weeks. Alternatively, microfilm or photostat copies can be made for retention. There is no charge for this service except that a nominal charge is made for photo copies ordered for retention.

I think readers will agree that there is abundant justification for the contention made at the beginning of this article that there is a wealth of little known scientific and technical information of an unrestricted nature available in this country. It is not possible here to catalogue every source of the documents received in TIDU and I have concentrated only on the main groups.

TIDU* has, of course, other duties and although space does not permit a detailed description of these mention should be made of its Technical Inquiry Service as this could be of great assistance to those seeking technical information. Many individuals and firms make use of this service for which no charge is made.

* The full address of TIDU is: Technical Information and Documents Unit, Department of Scientific and Industrial Research, Cunard Building, 15 Regent Street, London, S.W.1. Tel.: WHItehall 9788.

New Ideas at the British Association

Every year since the war there has been talk about the need for the British Association to alter the character of its annual meeting. But the next meeting turns out to be remarkably similar to its predecessor. Even the innovation, begun at the Belfast meeting of 1952, of special lectures for young people, and the big influx of student members which followed the introduction of the special students' subscription of half a guinea, did not seem to result in any deep-seated change in the character of the meeting as a whole. It would be fair to say that the meeting held at Bristol this year was "the mixture as before" except for one or two things. This year the junior members did more than just listen to lectures arranged for them by their elders; some of them participated actively in the meeting by reading papers, and in addition there was the very excellent schools' science exhibition in the College of Technology which was visited by a great many local people who otherwise would have had no direct connexion with any of the British Association activities and functions. Were these two events something more than just novel incidents? Could they be signs that something in the nature of a live "Junior British Association" is going to develop out of what was started at Belfast?

The young people who gave lectures deserve to be mentioned by name. First because they made an excellent job of preparing and delivering their papers; secondly because they may well have blazed a new trail which could profitably be widened at future B.A. meetings. The two schoolboys and two schoolgirls who talked to Section X described aspects of field work they had done. R. S. Cormack (Bristol Grammar School) reported results he and fellow members of his school's ornithology club had obtained from observations of differences in plumage of over 300 house-sparrows. J. J. Swift (Charterhouse) spoke of the progress of the nest-box scheme carried out at his school, and Miss Margaret Silcocks (Portway Secondary School) explained how the examination of a handful of barn owl pellets aroused the interest of a second-year form in the natural history of owls. The fourth paper was by Miss Felicity Scott (Westonbirt School, Tetbury), who talked about the results of an ecological investigation of the fauna of a tributary of the Bristol Avon.

B.A. members were full of praise for the schools' science exhibition. The school-children and the science teachers who prepared the exhibits richly deserved this praise. The two enthusiastic organisers of the exhibition—Mr. F. F. Glasspoole, the senior lecturer on science at Redland Training College, and A. Mattfield of the county education authority—can take great pride in the results of their efforts, which had resulted in contributions from over thirty schools in Somerset, Gloucestershire and Wiltshire. The whole show conveyed the impression that practical work in science and field study flourish in the West Country, which evidently enjoys the services of many talented science teachers. Some of the items were surprisingly good; to mention just one, there was an exhibit from La Retraite High School, a Bristol girls' school, on the solar eclipse of 1954. This included a fine set of photographs showing the full eclipse sequence, graphs of temperature and radiation measurements recorded during the event, and a very neat model showing the different phases of a solar eclipse.

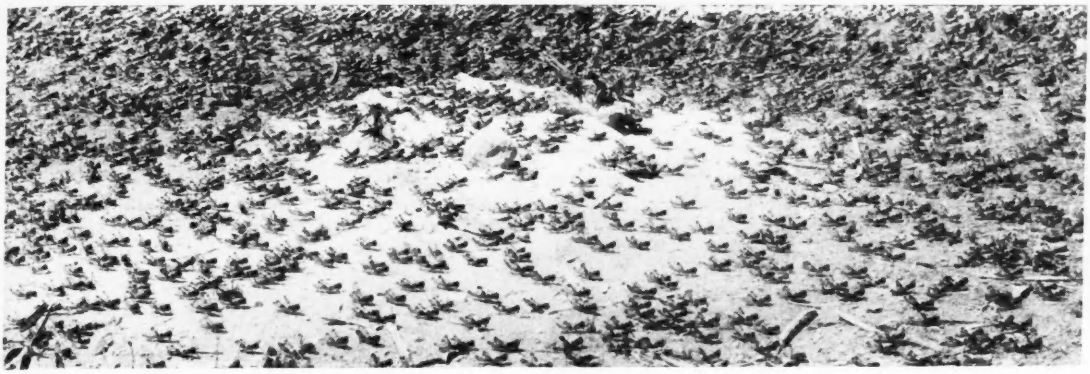
Apart from what some people called the Junior British Association in embryo, there was one other new feature this year. Films have been shown at other B.A. meetings, but this year there was a "Scientific Film Festival". This began auspiciously with the British premiere in a Bristol cinema of the film of the building of the Calder Hall atomic power station. Sir John Cockcroft introduced the picture.

Apart from the Calder Hall film, forty scientific films from thirty countries were shown in the hall of the College of Technology, and four of them had not been screened publicly before. These were: *Controlled Heat*, a Shell Film on automatic temperature control; *Chromatography*, a colour film made by Jack Chambers for the Education Foundation for Visual Aids; and two films from the National Film Board of Canada, *The Colour of Life* and *To Serve the Mind*. On the Saturday there was a special session of research films. Among them was a remarkable colour film by Dr. E. J. Ambrose and Dr. M. Abercrombie recording the growth and activity of living cells as seen through a Schmidt interference microscope; one sequence showed the destruction of cancer cells by the enzyme called ribonuclease.

An expert on scientific films, Dr. A. R. Michaelis, was responsible for running this Scientific Film Festival.

Among the most successful lecture sessions were those designed to bring together scientists of the different disciplines. The biological significance of DNA, the key material of chromosomes, was treated in this way on two separate occasions. The presidential address to the Chemistry Section by Sir Alexander Todd discussed nucleic acids and their function. This was followed by lectures by Prof. Stacey and Prof. Darlington, which proved to be just as intriguing as their titles—"Taking the nucleic acid jackets off bacteria" and "Nucleic acid: the midwife molecule". An equally large and mixed audience, including chemists, physicists and biologists, attended the other DNA session, where the speakers were Prof. Haldane, Prof. J. N. Davidson, Dr. M. F. H. Wilkins and Dr. F. H. C. Crick. Readers will recall the valuable article on the structure and function of DNA which Dr. Crick contributed to DISCOVERY in January 1954; the key diagram from that article turned up at Bristol as a lantern slide in the middle of Prof. Darlington's lecture!

The education of scientists was discussed at several sessions, and we shall be printing some of the papers on that topic in our next issue.



THE DYNAMICS OF ANIMAL POPULATIONS

PROF. V. C. WYNNE-EDWARDS

Regius Professor of Natural History, Marischal College, University of Aberdeen

The "balance of nature" long ago became a familiar phrase, though to most people its meaning may never have been very clearly defined. It expresses the general idea that the inter-relationships between living creatures seem to form a fairly stable, ordered and self-sustaining network, and it implies that forces exist which tend to repair the balance and restore the pattern when it has been disturbed.

The relationships of living creatures to one another may be simple or complex, close or remote. Animals compete with others of their own kind for commodities like food and shelter when these are in short supply. They may compete similarly with other species if they share the same needs; or they may consume them for food, or submit to them as predators, or suffer from them as parasites. In each of these relationships the consequences must be largely governed by the interplay of supply and demand, in which the animals' own numbers on the one hand, and those of their food organisms or enemies on the other, play the decisive parts. Thus it comes about that it is one of the fundamental problems of ecology to understand the natural forces regulating the numbers of animals.

Dr. Lack's latest book* deals with this subject and is therefore of great general interest to biologists. He himself is primarily an ornithologist, and is director of the Edward Grey Institute of Field Ornithology at Oxford. Birds, being a specially attractive and conspicuous group of animals, draw the attention of many students, and in fact a very large contribution to the study of "population dynamics" has been made by ornithologists during the last twenty years. Among them Dr. Lack himself has played the leading part in this country. The factual material with which the book is richly supplied is predominantly concerned with birds, though three of the twenty-four chapters deal specifically with other animals, and the latter are given frequent mention elsewhere throughout the book. It is a reasonable presumption in any case that some if not most of the basic principles in the regulation of numbers will turn out in the end to be the same for all animals.

At the present stage of our knowledge these basic principles are far from being securely established. Dr. Lack's book is not the last word on the subject: indeed he says modestly that it is a signpost, and that he hopes that the sign points in the right direction. Its value and importance is in the presentation and synthesis of an enormous volume of previously scattered literature, in a form in which students can ponder and criticise it, and thereby stimulate their own ideas and researches. He says (p. 4): "The literature on bird populations is so scattered that I found it necessary to read through all the ornithological journals and books published during the last seventeen years", a Herculean labour, needless to say, but as a by-product of it has emerged a list of almost a thousand references which is printed at the end of the book. This is a bibliographical compilation of great value in itself.

It is made clear at the outset that, though populations of animals may often be observed to undergo conspicuous changes in numbers, these changes are actually small compared with what is theoretically possible. In fact it is the relative stability, and restricted range of fluctuation, which is the fundamental characteristic. What the student of animal population is much concerned with, therefore, are the forces or factors which restrain the increase in numbers beyond a definite upper limit, or maximum density.

Clearly it is necessary for continued survival of a group of animals to budget for a surplus, by being able to reproduce faster than the minimum rate of inescapable mortality. Budgeting for a surplus would tend to increase the numbers and the population density, and thereby to promote a growing pressure of competition between members of the group. Increased competition may bring greater exposure to danger because the best cover is overcrowded, or an insufficiency of food, which

* *The Natural Regulation of Animal Numbers.* By Dr. David Lack, F.R.S., Oxford: Clarendon Press, 1954, 343 pp., 35*s.*

may in turn induce a greater liability to disease. There is no need to stress that overcrowding can step up the death-rate to a tremendous extent; sooner or later it generally outstrips the birth-rate, and then there follows a decline in numbers and a return once more to lower mortality pressure. Natural populations are subject to a number of factors which exert this kind of varying influence and are said to be *density-dependent*; in great measure they are responsible for the relative stability of numbers, and the balance between one species and another, which is observed to exist.

Thus far we are on fairly solid ground, but at present it does not extend much further. Mortality is not the only quantity which is subject to density-dependent influence: natality can be similarly affected. The reproductive rate in many animals is sensitive to changes in the state of the habitat, and to the influences of freedom or crowding, plenty or hardship.

It is not difficult to see that, in the course of evolution, the reproductive rate of every species has been subject to natural selection, and is normally well adapted to the conditions of life of the species. Many kinds of parasites, for example, absolutely depend on some specific host appearing on the scene at a certain crucial stage of their life-history, and coming to their rescue, sometimes in very improbable circumstances; the chance of individual success is so infinitesimal that they must devote almost the whole of their lives and energies to prolific reproduction. The animals which protect their young longest and in the greatest security, on the other hand, often produce as few as one offspring a year.

If the numbers in the population are to remain on the whole stable, then the total number of births and deaths must be equal, at least when summated over a sufficiently long period of time. Though each is subject to density-dependent effects, yet births and deaths are often far removed in time and place, and their immediate causes are generally quite unconnected. If the numbers of each turn out to be the same, then it must have been necessary for one to be trimmed to match the other, unless of course both have participated mutually in reaching a balance. Dr. Lack has attempted to show that in fact one of the three of these possible alternatives is the normal result of natural selection, namely, that the animal's rate of reproduction is pegged as high as can safely be maintained, regardless of the relative hazard or security of its way of life, and thereafter the mortality takes care of the varying surplus, be it great or small. According to his view, natality is the independent variable, and mortality adjusts itself (through density-dependent effects) to match it.

This is a view which many zoologists find it very difficult to accept. "Wrong ideas," says Dr. Lack (pp. 3–4), "have been absorbed into current thought without having been explicitly discussed." One of the ideas adopted by him which he says have been found most particularly difficult is this very one, "that the reproductive rate . . . is not, as often supposed, adjusted to the mortality rate of the species . . .": rather, he believes, the opposite holds, namely that the mortality adjusts itself to the reproductive rate. He persists in this view throughout the book, obviously not unaware that it meets with uncomfortable difficulties and contradictions: "In fish, marine invertebrates, and insects there is a broad correlation between the number of eggs laid and the degree of safety of the larvae, and from this it has often been argued that the species with brood-protection do not have to allow for such heavy losses. The general correlation is undoubted . . . the conventional deduction from it . . . is wrong. Natural selection cannot favour a smaller egg-number as such." (p. 48).

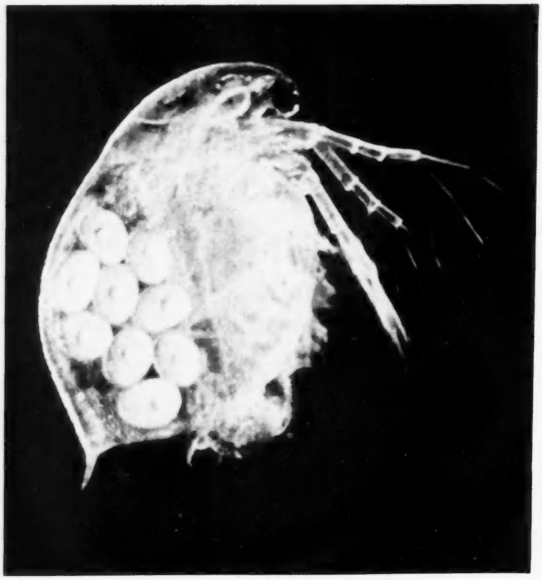
The last sentence is really the key to the paradox: but it is itself a hypothetical assertion. The argument for it might be given somewhat as follows: Natural selection acts by discriminating against the less fit among the population; fewer of them reach maturity, and their expectation of adult life is less, so that their chances of perpetuating themselves are diminished compared with those of their fitter brethren. The fitter therefore contribute a disproportionate share of offspring to the next and subsequent generations, and thereby the stock is improved. Any individual which contributes more than its share to posterity must be favoured by selection, and any which contributes less than its share (i.e. has a smaller egg-number than average) is doomed to decline.

One may well suspect a fallacy here. As the March Hare said to Alice, "Why, you might just as well say that 'I see what I eat' is the same thing as 'I eat what I see'!" Selection would be bound to favour the perpetuation of the fittest if the reproductive rate of all individuals was uniform; but it is not, and those which are actually most fecund and contribute the most to the next generation are by no means necessarily the fittest, as may be seen in certain human communities today.

If the most fecund are not the fittest, the stock may deteriorate in quality instead of improving, and in the course of time will very likely fall on evil days, and perish. Selection will then have exacted its retribution against the stock which was over-prolific, and at the end of the day left the field open to other stocks of more moderate fecundity. It would appear that selection can just as readily favour a lower as a higher reproductive rate, permitting always the survival of those populations which continue to live in harmony with their environments, and eliminating those whose balance has got out of control.

If the contrary to Dr. Lack's view could be accepted, namely that the reproductive rate is just one of a host of physiological adaptations, adjusted to meet the exigencies of the environment, we should be on more familiar and comfortable ground. In fact, new and promising-looking vistas would open up before us. We recognise in the wonderful adaptations of animals and plants their ascendency over their environment, and the means by which their survival is safeguarded. As long as their adaptations are sufficiently perfect, they hold the trump cards in their own hands.

One of the most important of all adaptations, we might expect, would be the means of controlling their own population, and not having to rely entirely on external agents to do the job. We see in many kinds of



The water-flea *Daphnia* with young developing in the brood-pouch. The denser the population of this freshwater organism, the smaller is the size of the brood.

animals elaborate social organisations, such as the territory system in birds, whose function is to disperse the population at a density suitable to the particular habitat —to avoid overcrowding in one place and vacant living room in another. This is an adaptation of behaviour which is directly concerned with the control of numbers. There appear to be many others aimed in the same direction—adjustments of the reproductive rate, for example, in inverse ratio to population-density, an example of which is given for the water-flea *Daphnia* (p. 123): "When numbers were high, the *Daphnia* were short of food and laid fewer eggs than usual, so that the numbers in the next generation were smaller. Conversely, when numbers were low, the reproductive rate was higher and the next generation larger." Another example can be taken from p. 241: " In experiments on the rice-beetle . . . emigration was found to occur whenever the numbers rose to a certain level. . . . If emigration was prevented, so that numbers rose above this level, the females laid fewer eggs and the adults ate many of the rice-grains already inhabited by larvae."

If such simple means as these could be available to every species to control its own population dynamics, it would certainly be their ace of trumps in the struggle for existence. It would seem to be quite an extraordinary situation if such intrinsic control had not been seized and developed and become a normal and universal phenomenon in nature. This line of thought is nowhere pursued by Dr. Lack, nor does he discuss the possibility that the natural regulation of animal numbers may be something that, in the last analysis, each species is competently adapted to do for itself.

It is no doubt a heritage of the Darwinian tradition that we tend to focus our attention on the struggle for existence, and the marvellous adaptations of animals for survival—their cryptic colours, swift movements, impenetrable defences, keen weapons and tenacity to life. These stand them in good stead in times of danger and stress; but for many animals and plants real emergencies are infrequent and short-lived, and much of their lives may actually be passed in genial surroundings, which do not seriously tax their great adaptability and resource. On the outer perimeter of an animal's geographical range it may indeed be reaching a threshold beyond which the bare necessities of life are lacking, and then it will probably be touch-and-go whether it succeeds in pushing the frontier forward, or manages just to hold its ground, or is forced to withdraw. The struggle may sometimes be a desperate one, unsuccessful even for the fittest; but far off in the heart of its domain there may be places where, by contrast, every desirable condition of life seems to be abundantly fulfilled. We do not stop to reflect that in this Elysian environment there may be just as great and indispensable a need of adaptations to curb the increase of numbers beyond the optimum density, and avert the constant threat of over-population, attended by famine, disease and perhaps ruin of the resources of the habitat. The hardest struggle must obviously not be identified with the best world, nor with the surest chances of survival.

If such views as these could be substantiated, the control of numbers would appear not as something passive, which just happens, but as something active and constructive, important to survival and therefore developed and fostered by natural selection. It would have a single purpose, to secure proper dispersion thoughout the habitable environment, so that the population-density was as near as possible the optimum for the particular habitat in each part of the range. The control of population-density would be the primary end, the limitation of absolute numbers having no particular value otherwise.

It is tempting to pursue such speculations further, but one more corollary must suffice. The "best world" would presumably be the one which continued indefinitely to yield the richest harvests to the largest number. If the food resources of the environment was regarded as capital, and the harvest they yield as interest, expenditure ought not to be allowed to exceed the average rate of interest, or it would start eating into the capital, and that would begin a spiral of diminishing returns. The optimum density of population, in these circumstances, would be the maximum density which the resources would support permanently, without being impaired. Then in any food-chain, each link would itself be living at the greatest density and yielding the biggest harvest or highest rate of interest to the next link above. It is as interesting as it is unexpected that the optimum and maximum should appear to coincide.

(*The illustration on p. 432 shows hoppers of the Desert Locust,* Schistocerca gregaria, *on the march in Northern Tanganyika. A "Shell" photograph.*)

THE BOOKSHELF

Frontiers of Astronomy

By Fred Hoyle (*London, Heinemann, 1955, 376 pp., 59 plates, 67 text illustrations, 25s.*)

Nine years ago an excellent popular book, the first of the Sigma introductions to Science, was written by Dr. David S. Evans, now Chief Assistant at the Royal Observatory, Cape of Good Hope. It was called *Frontiers of Astronomy*, and one cannot but regret that precisely the same title should have been given to Mr. Hoyle's latest work. The description is, indeed, accurate enough in both cases, in so far as each of these books goes to the limits of ascertained knowledge at the time of its writing—Mr. Hoyle's, in fact, beyond those limits and into the realms of highly ingenious speculation.

Yet, at the frontiers, there must necessarily be speculation as to what lies beyond; otherwise the frontiers would never be extended. Mr. Hoyle's propositions are all based upon careful reasoning from substantial premises, the weapons of astronomical theory being, as he says, "derived directly from physics, chemistry, aerodynamics, and a host of other sciences in a lesser degree". He lays great emphasis on his belief that nothing has happened by chance—that a logical explanation exists, and may be found, for every fact discovered. At the same time, he does not hesitate to mention instances where his views have been modified since he wrote his earlier and widely-known book *The Nature of the Universe*, although he is still a firm adherent of the steady-state theory, with its corollary assumption of the continuous creation of matter. This theory, he points out, has one advantage in that it is "vulnerable to observational attack", since in a steady-state universe all observable features must arise from processes that are still in operation, whereas the explosion or "big bang" hypothesis, according to which cosmic evolution began suddenly, deals with "the consequences of processes that are over and done with". Undeniably the steady-state theory is attractive to many minds, but Mr. Hoyle is surely justified in claiming that "it is not an emotional preference to attempt to establish a theory that would place us in a position to obtain a complete understanding of the Universe". The last five words of this sentence are, perhaps, too optimistic, especially as Mr. Hoyle himself admits, only a few paragraphs earlier, that investigation of both the ultra-small and the ultra-large ends in mystery, and that the two mysteries may turn out to be closely connected. But will that resolve the essential mystery?

These, however, are deep and recondite matters, which come at the end of the book. What should appeal to the ordinary reader is the wide range of the contents, beginning in quite homely fashion with the length of the day and the causes of ice ages, and finishing with the hardest problems of cosmogony. The origin of the solar system is discussed at some length, and Mr. Hoyle has a new suggestion to make regarding Venus, whose perpetual mantle of cloud veils her so inscrutably. She may, he thinks, have oceans of oil, which fill her atmosphere with smog and which give rise to sufficient tidal friction to account for her slow rotation. It is a strange and rather irritating paradox that the nearest to us of all heavenly bodies save the Moon should be so constituted as to baffle visual examination.

But the solar system becomes less and less important as the tale of astronomy unfolds—the more so now that it is no longer thought to be a unique phenomenon peculiar to our Sun, but rather an example of what may have developed around most of the stars. Hence Mr. Hoyle concerns himself at much greater length with the problems of stellar evolution, the structure of the Galaxy, the origin and nature of the cosmic rays, and the formation of the extra-galactic nebulae. He has, in fact, packed into one volume a far greater and more varied amount of information, argument and theory than is usually to be found in a single book; and if some of the matter is difficult, the fault lies in the inherent complexity of the subject, and not in Mr. Hoyle as a writer. Modern ideas about the universe, necessarily lacking in finality though they are, possess a stimulating quality such as few other branches of thought can offer; and a book of this type, which represents popularisation at its highest level, aims at the kind of readership which some twenty years ago made the works of Jeans and Eddington best-sellers.

E. N. PARKER

Analytical Chemistry—The Working Tools, vols. 1 & 2

Edited by C. R. N. Strouts, J. H. Gilfillan and H. N. Wilson (*London, Oxford University Press, 1955, 1067 pp., 5 gns.*)

This work represents a further step in the fulfilment of the undertaking made by Lord McGowan to make generally available some of the technical information accumulated by I.C.I. Since it was intended originally to serve as a handbook which would promote uniformity in methods throughout all the various divisions of I.C.I., it can fairly be described as comprehensive in its scope. The ground covered by the first volume is roughly the techniques and individual methods of straightforward physical measurements and chemical analyses. The second volume takes in the more highly instrumented techniques, such as polarography, electrometric titration, colorimetry and spectroscopy, x-ray diffraction and chromatography. It concludes with a section on statistical methods which are now essential for all work of this kind.

Both volumes are well illustrated and the text does not hesitate to mention apparatus commercially available and who makes it. This beautifully produced work should find a place in any laboratory with chemical analyses to do, and it is certainly excellent value at the price.

F. E. W.

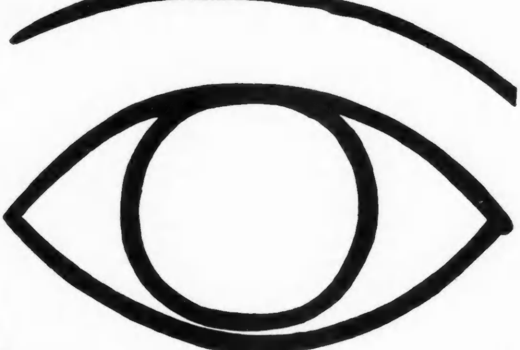
The Chemistry of Micro-Organisms

By Arthur Bracken (*London, Pitman, 1955, 343 pp., 30s.*)

The custom of delivering a course of lectures on a given subject and later modifying them into a book is becoming increasingly widespread. Frequently the results are excellent; all Oxford-trained chemists of the last two or three decades participated in the gestation of the late Prof. Sidgwick's *Chemical Elements and Their Compounds*, and the result was one of the most valuable textbooks in its field.

Unfortunately Dr. Bracken's lectures have not yielded a book of this class. It does not deal with the chemistry of micro-organisms in any sense that an ordinary microbiological chemist would understand these words, being rather an account of the chemistry of the numerous end products of mould metabolism that have come to be associated with the excellent work of Prof. Raistrick and his colleagues. There is also a good chemical account of the antibiotics. Dr. Bracken's account of these two subjects is excellent. He obviously has the material at his fingertips and his account of how these strange compounds have been isolated, how their chemical structures have been established, often by synthesis as well as degradation, is clear and readable. Moreover, it fills an important gap, because a coherent elementary account of the organic chemistry and interrelationships of these compounds is lacking from contemporary bibliography.

Had Dr. Bracken restricted his book to these subjects—which occupy roughly Chapters 5 to 10—it could have been recommended unreservedly. Unfortunately, he has chosen to cover, ostensibly, the whole of microbial chemistry, and the results are little short of disastrous. The biological background provided in the opening and concluding chapters is superficial, misleading, sometimes self-contradictory, often inaccurate and at times nonsensical. We are told, for example, that moulds differ from bacteria in that they produce hydroxylated non-volatile acids such as citric, oxalic, malic, fumaric and itaconic because their metabolism is "more oxidative" than that of bacteria; the latter consequently produce



acetic and other non-volatile acids (p. 55). This is (*a*) factually wrong, since the majority of bacteria produce carbon dioxide and water only; and (*b*) meaningless, since there is good reason to believe that all the acids mentioned, except possibly oxalic, take part in the terminal respiratory cycles of most bacteria so far investigated; the epithet "more oxidative" therefore conveys nothing.

Elsewhere we are informed that the enzymes of one organism "possess a higher oxidising potential" than those of another because the diphenylquinone that accumulates in its cultures is hydroxylated (p. 162). On p. 1 Dr. Bracken writes: "bacteria lead a completely sex-free life as far as we know at present"; fortunately the work of Lederberg, dating from 1946, had come to his attention by the time he reached p. 311 and this statement is there contradicted. Penicillin acts, we are told, by producing giant forms "and the operation of the 'scale-up' effect soon produces the death of the cells" (p. 37); on p. 315 the myth that the clinical use of penicillin has led to the "development" of resistant strains is perpetuated, in spite of the fact that Prof. Chain himself could write last year: ". . . as far as I am aware, not a single authentic case has been reported of a genuine development of resistance to penicillin during clinical treatment" (*Antibiotics and Chemotherapy*, Vol. 3, p. 215, 1954). The biosynthesis of the benzene ring in micro-organisms is discussed with neither reference nor allusion to the work of B. D. Davis; the account of the autotrophs on p. 22 is confusing; and Dr. Bracken's generalisation about the distribution of nutritional requirements in micro-organisms would be accepted by few microbiologists. He maintains that the smaller the organism the more exacting it is, for it has insufficient space for all the enzymes it would otherwise need (p. 17). How large the autotrophs ought to be!

All this, and more, would matter little if the book were intended for microbiologists. In the hands of the uninitiated, however, it could prove misleading on a number of points.

It is well set out without illustrations; the English is lively and the index appears comprehensive.

JOHN POSTGATE

Free Diving

By Dimitri Rebikoff (*London, Sidgwick & Jackson, 1955, 216 pp., 25s.*)

For aqualung enthusiasts this book can be recommended since it is full of technical data about diving equipment, and about underwater photography and filming. The author is a recognised expert on this branch of photography and invented the "torpedo camera" which has simplified the work of obtaining good underwater pictures in colour.

Mathematics in Action

By O. G. Sutton (*London, Bell, 1954, 226 pp., 16s.*)

This book may be read with profit and delight by the embryo scientist, or the developed scientist who is not primarily a mathematician or whose mathematics are yet in the development stage. It must be stressed that the "Action" of the title takes place in the physical world. The worlds of economics, agriculture biology, psychology and education are *ultra mures*. Within the physical world Sir Graham Sutton weaves a broad and easily developed pattern depicting the application of mathematical logic and procedures to a range of problems arising in the fields of ballistics, waves in their variety, flight and prediction. This fascinating and stimulating volume would gain from the addition of a selected bibliography for further reading.

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